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A Preferred Spare Decision Support
System Incorporating
A Life Cycle Cost Model

THESIS

Thomas A. Garin
Captain, USAF

AFIT/GOR/ENS/90M-6

Approved for public release; distribution unlimited

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A Preferred Spare Decision Support System Incorporating a Life Cycle Cost Model

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

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Captain, USAF

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Preface

This thesis effort would not have been possible without the support and encouragement of many people. I am especially grateful to Lt Col John "Skip" Valusek, my advisor, for his guidance and to Mr Rob Lucas, HQ AFLC/MMISA, and Mr Jeff Vineyard, HQ AFLC/MMMCS, for their time and assistance. Likewise, I appreciate the time of all the people who answered my questions at HQ AFLC, ASD, and other DOD agencies. But most of all I want to thank Lois for understanding.

Thomas A. Garin

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Abstract

Life cycle cost

The purpose of this thesis was to define and validate the factors needed to build an LCC model to determine preferred spare acquisition strategy and develop a Preferred Spare LCC model. The study had five basic sub-objectives: (1) Identify and understand the information used by item managers when they acquire preferred spares; (2) Obtain a comprehensive understanding of the preferred spare decision process; (3) Evaluate the CASA model with the intent of understanding and incorporating specific equations in the LCC model; (4) Develop a methodology within the LCC model for examining different preferred spare acquisition strategies; and (5) Develop a Preferred Spare LCC model. Keywords: Theses, Spare Parts, [illegible]

The Decision Support System was selected as the methodology for the problem formulation. Concept maps, feature chart, and storyboards were developed to understand the preferred spare decision process. A Preferred Spare LCC model was developed using cost equations from the CASA model. The LCC model runs on the Lotus 1-2-3 spreadsheet. The model is quick, easy to operate, easy to understand, and the data inputs are readily available.

CHAPTER I

INTRODUCTION

The Air Force Logistics Command (AFLC) provides logistic support to all Air Force activities. Since logistics has been a difficult task for armed forces throughout history, the AFLC has employed the concept of the Air Logistics Center (ALC). The ALCs are located at Oklahoma City, Ogden, San Antonio, Sacramento, and Warner Robins. Each ALC specializes in maintaining different aircraft and systems.

The ALC consists of four mission directorates and the usual support elements. The four directorates are (1) Material Management, (2) Maintenance, (3) Distribution, and (4) Contracting and Manufacturing. The Directorate for Material Management (MM) is responsible to the ALC commander for worldwide logistics support management.

Within MM is the Item Management Division (MMI). Item management includes all supply functions for each individual item. The process begins with the purchase of the item and ends with its disposal. Included within item management is the concept of product improvement. One way the Air Force makes product improvements is to buy preferred spares that improve hardware components of weapon systems. The following sections define the preferred spare, review the problem, state the need and purpose for the thesis, and list the sub-objectives.

The Preferred Spare

A preferred spare is a spare that has at least one beneficial quality over an existing part. Common beneficial qualities include improved cost savings, reliability, safety, maintainability, and combat capability. Associated with each beneficial quality is either a real cost savings or an intangible cost savings.

Cost Savings. A real cost savings is one with an associated dollar value. For instance, improving the reliability of an item can result in a real cost savings. The cost to support the item should decline because less maintenance actions are required.

An intangible cost savings, on the other hand, is one without an associated dollar value. For instance, a pilot using a navigation system with a spinning mass gyro may identify his aircraft's position in about 2 to 3 minutes. However, if the Air Force replaced the old gyro with a new ring laser gyro that same pilot can determine his location instantaneously. It is more difficult to place a dollar value on this technology improvement.

Fit and Function. The preferred spare must also match the existing part in both fit and function. Recently, the Air Force replaced the aluminum rotary blades for the

Sikorsky HH-53 helicopter with rotary blades made out of titanium. The new titanium blades matched the old aluminum blades in both fit and function.

Exceptions to this rule are stated in the regulations. According to AFR 57-4, "Modification Approval and Management Regulation", HQ AFLC/MM may approve minor fit or function changes if the new part results in a more timely or cost effective solution to a deficiency (AFR 57-4,1987:9).

Furthermore, the AFLC draft supplement regulation to AFR 57-4, "Improved Item Replacement Program" (IIRP), says the associated minor fit rework shall not require more than eight clock hours or 25 man-hours (IIRP,1988:2).

Acquisition Level	Program Manager	Program Executive Officer	Acquisition Executive
$1 M/yr or $15 M total	Initiating Division	ALC/MMM	ALC/MM
$15 M/yr or $50 M total	ALC/MM	HQ AFLC/MMM	HQ AFLC/MM
$25 M/yr or $100 M total	ALC/MM	ALC/CC	HQ AFLC/MM
More than $25 M/yr or $100 M total	USAF/LEX/LEY	HQ AFLC/MM	HQ AFLC/CC

Table 1. Approval and Authority Levels (IIRP,1988:4).

Approval and Authority. Item managers are authorized to purchase preferred spares in sufficient quantities for

100 percent replacement. Table 1 shows the approval and authority levels as stated in the IIRP.

Attrition. A preferred spare may enter the supply system through normal attrition or forced attrition. Normal attrition is the replacement of the part when it actually fails. Under normal attrition, the preferred spare is simply interchanged and substituted (I&S) for the part being replaced.

Forced attrition, on the other hand, is the replacement of a part during another maintenance action without regard to the condition of the part being replaced. For example, the mechanics working on an aircraft in phased maintenance may replace a part with a preferred spare, even though the original part has many hours of serviceable life remaining. However, if the aircraft is brought into the hangar for engine maintenance and the preferred spare is a part for the cockpit, then the preferred spare is not interchanged at that time.

Forced attrition may occur only when the old part is unsupportable, or the new part offers a significant state-of-the-art improvement. An old part is called unsupportable when it causes unacceptable reliability or maintainability (IIRP,1988:4). This means the part may have a low meantime between failure (MTBF), a low meantime between maintenance action (MTBMA), or excessive maintenance man-hours associated with it. A new part offers significant state-of-the-art improvement over an existing part if it can be shown by economic analysis that the Air Force can reduce costs by buying it (IIRP,1988:4).

Preferred Spare Use. For the past several years, the Air Staff has promoted the expanded use of preferred spares because they are a quick and relatively cheap way to make product improvements (Stapleton, 1988:2). By the end of summer 1988, the Air Force had over 36 active preferred spares valued at $1.7 billion (Stapleton, 1988:2). The following table shows some examples of actual preferred spares and the associated cost with each.

	PREFERRED SPARE	AMOUNT BUDGETED
1.	ALQ-137 Countermeasures System	$109.3 million
2.	Main Gear Box	$27.2 million
3.	Synchrophaser	$4.8 million
4.	ALT-32 Transmitter	$15.8 million
5.	Rotor Blade	$28.8 million
6.	Tail Warning System	$89.5 million
7.	LN-93 Ring Laser Gyro	$102.4 million
8.	Pacer Grade	$66.9 million
9.	Vane Changeout	$7.1 million
10.	Anti-Ice Duct	$1.1 million
11.	F100 Engine Conversion	$14.6 million
12.	Event History Record	$25.2 million
13.	Gearpump/Bypass	$97.3 million
14.	Improved Life Core	$1,024.5 million

Table 2. Preferred Spares and Cost (Stapleton,1988:21).

Presently, HQ AFLC replenishment spares (BP15) budget managers "annually budget over $450 million for 100 percent preferred spares" (Lucas,1989:1).

Problem Statement

A recent Air Force Audit Agency (AFAA) audit conducted between September 1987 and February 1988 at HQ AFLC, Warner Robins, Oklahoma City, and San Antonio ALCs revealed a problem implementing the preferred spares program at the ALCs. Specifically, the AFAA draft report of the audit, "Management of the Preferred Spares Program" (Project 7126118), showed "preferred spares initiatives had been approved without the aid of economic analysis" (Stapleton, 1988:4). This made the commitment of Air Force funds questionable.

One reason economic analysis was not performed by item managers at the ALCs was because AFLC regulation 57-11 did not specifically require it. HQ AFLC responded to the audit by making the necessary minor revisions to AFLC regulation 57-11. In addition, HQ AFLC wrote the AFLC draft supplement regulation to AFR 57-4, IIRP. The IIRP is intended to be a stand-alone regulation outlining the policies and procedures to govern the current 100 percent preferred spares program. The Air Staff is currently reviewing the proposed AFLC supplement regulation.

According to the IIRP, a complete life cycle cost

(LCC) study shall be completed for each preferred spare initiative.

> The LCC will include considerations for not only introducing the item into the supply system, but at what rate, including or not including the forced attrition of the installed items, the impact of repair budgets as a cost driver, the impact on all other budget programs such as support equipment, special tooling, and bit and piece part support and the impact of WRSK/BLSS sustainable funding. (IIRP,1988:2)

The IIRP also required HQ AFLC/MMM, the Directorate of Material Requirements and Financial Management, to select the LCC model. HQ AFLC/MMM selected the Cost Analysis and Strategy Assessment (CASA) model.

The CASA model was derived from Honeywell's Total Resource and Cost Evaluation (TRACE) family of models (CASA,1988:1). The models operate on the Zenith-248 personal computers and feature individual program options for basic LCC analysis, sensitivity analysis, Monte Carlo simulation, LCC comparison, and its own data file editing program. The item managers, however, could not operate the complicated model and promptly return it to HQ AFLC. Mr. Ron Rosenthal, Spares Branch for Central Procurement Division (HQ AFLC/MMMCS) and former item manager, stated several reasons why the CASA model was returned: 1) the model is difficult to operate, 2) the results are difficult to understand, 3) certain data are unavailable, and 4) the analysis takes too much time. (Rosenthal,1989).

Furthermore, the CASA model requires 320K of Random Access Memory (RAM). Attempting to run the models with less RAM will 'cause an 'Insufficient Memory' error or produce unpredictable results' (CASA,1986:1).

Requirements

Mr. Rob Lucas, Analysis Branch for Material Management (HQ AFLC/MMISA), summarized the requirements for this project and referenced a 12 Aug 87 message sent by Mr. Jeff Vineyard, Spares Branch for Central Procurement Division (HQ AFLC/MMMCS), to Mr. Mike Collier, Systems and Applied Sciences Corporation,

> Mike, I believe we have a perfect/high priority candidate for a study if that study would result in a standard software package for the Z-248 plus documentation that the government would own. This project is the result of needs identified in support of BP15 in the 100% replacement/preferred spare area.
>
> What we need is a lightweight/easy to use AI/direct use (menu driven) program to test the various economic/acquisition plans for the 100% replacement/preferred spares budget/execution efforts. I can detail the various inputs that would be required and the expected inputs [outputs]. It would have to be flexible to produce several possible solutions dependent on the replacement/acquisition strategy. It must be simple enough for the avg IM/ES to use and pass audit not only here but from AFAA/GAO etc. It must produce a standard output that would show the various solutions via graph and numeric. (Vineyard,1987:1)

Purpose Statement

The purpose of this thesis is to define and validate the factors needed to build an LCC model to determine preferred spares acquisition strategy and develop a Preferred Spares LCC model.

Sub-objectives

There are several steps that must be taken to solve this problem:

1. Identify and understand the information used by BP15 budget managers when they acquire preferred spares;

2. Obtain a comprehensive understanding of the preferred spares decision process;

3. Evaluate the CASA model with the intent of understanding and incorporating specific equations in the LCC model;

4. Develop a methodology within the LCC model for examining different preferred spares acquisition strategies; and

5. Develop a Preferred Spares LCC model.

Summary

This chapter introduced the topic of preferred spare. The Air Force buys preferred spares to make hardware improvements to weapon systems. However, a recent Air Force audit revealed that the Air Force needs a tool to help decision makers perform economic analysis regarding preferred spares. The purpose of this thesis is to define and validate the factors needed to build an LCC model to determine preferred spares acquisition strategy. Chapter two discusses the subject of Decision Support Systems (DSS) as a methodology for the problem formulation. Chapter three reviews the development of the concept map, feature chart, and storyboards to understand the preferred spares decision process. Chapter four discusses the conversion of CASA model cost equations to the Lotus 1-2-3 spreadsheet. Chapter five contains the results, conclusions, and recommendations.

CHAPTER II

METHODOLOGY

The new IIRP requires HQ AFLC/MMM to supply item managers with an LCC model to use when making decisions concerning preferred spares. The intent of this thesis is to develop an LCC model called the Preferred Spare Life Cycle Cost Model and to incorporate it into an appropriate DSS. The following paragraphs review the subject of DSS. Specifically, the discussion covers its definition, its description, and an example.

The Definition of a DSS

Although it is quite difficult to get members of the DSS community to agree on a definition, it is possible to describe the class of information systems that DSS comprise. According to Sprague and Carlson,

> DSS comprise a class of information system that draws on transaction processing systems and interacts with the other parts of the overall information system to support the decision-making activities of managers and other knowledge workers in the organizations. (Spague & Carlson,1982:9)

In the early 1970's, Michael S. Scott-Morton used the term 'management support system' to begin articulating the concepts involved in DSS (Sprague & Carlson,1982:4). By focusing on the decision, Scott-Morton distinguished this new system from other Management Information Systems (MIS).

The DSS can be distinguished from the MIS still further. For instance, analysts generally apply the DSS to semi-structured or unstructured problems. Keen and Alter observed, "they tend to be aimed at the less well structured, underspecified problems that upper-level managers typically face" (Sprague & Carlson, 1982:6).

Other characteristics of a DSS include the following:

1. flexible because the decision process is unlikely to be repeated exactly,
2. user initiated and controlled,
3. provide the user with graphical support,
4. evolve over time (adaptive design), and
5. easy to use.

The Description of a DSS

This section examines the DSS from three different perspectives: the user's, the builder's, and the designer's.

The User's Perspective. The user is a person who makes decisions through a process. Herbert A. Simon characterized the decision making process with three main steps:

1. The first step is "Intelligence" or problem formulation. This occurs when decision makers search "the environment for conditions calling for decisions" (Sprague

& Carlson, 1982:26).

2. The second step is 'Design' and involves formulating alternatives. The decision maker invents, develops, and analyzes possible courses of action' (Sprague & Carlson, 1982:26).

3. The third and final step in the process is 'Choice'. This occurs when the decision maker selects a particular course of action and implements the decision (Sprague & Carlson, 1982:27).

The Builder's Perspective. The builder is the person responsible for the computer-based tools and techniques required by managers for decision support (Sprague & Carlson, 1982:28). He is concerned with the dialog component, the data base component, and the model base component of a DSS.

The dialog component is the interface between the user and the system. Hence, much of a DSS's power, flexibility, and usability characteristics come from the dialog component (Sprague & Carlson, 1982:29).

J. L. Bennett divides the dialog component into three main parts: what the user sees, what the user must know, and what the user can do in communicating with the system (Sprague & Carlson, 1982:30). As far as the user is concerned, the dialog is the system.

The data base component is the management of information needed to make a decision. If the data exists and is accessible to the user, then the user needs only to convert the data into a form that will support the decision making process. However, if the data does not exist or is not available, then a data base must be built and directions provided on how to manage it.

Sprague and Carlson provide a partial list of capabilities required in the data base area (Sprague & Carlson,1982:32):

1. To combine a variety of data sources.
2. To add and delete data sources quickly and easily.
3. To portray logical data structures in user terms.

The model base component is the management of models and modeling activities such as running, changing, and inspecting models. It also includes clearly communicating model assumptions to the user as a means to ensure proper use of the models. Therefore, model assumptions should be documented in the DSS while the model is being developed. Sprague and Carlson provide a key list of capabilities for DSS models (Sprague & Carlson, 1982:33):

1. To create new models quickly and easily.
2. To maintain a wide range of models.
3. To interrelate these models.

<u>The Designer's Perspective</u>. The designer is the person who facilitates the DSS implementation. He

coordinates communication between the user and the builder by helping the user to understand the decision process and the builder to support it.

The designer uses an adaptive design approach that "starts small and grows" (Valusek,1989). The designer meets with the user to identify the starting point and to determine what is needed to grow once the "kernel" is in place. The kernel is the focus of the decision process. The adaptive design process is a process of learning and evolution and it is the target of research at the Air Force Institute of Technology (AFIT). The methodology being investigated includes using the concept maps, storyboards, user driven evaluation, and the resulting kernel.

Concept Map. The designer begins the process by developing the concept map. The concept map is "an educational technique used to communicate knowledge and understanding" (Valusek, 1988:107). It is a visual aid showing the key concepts in a decision process. The designer meets with the expert to acquire the necessary background information. Any one session should last no more than one hour because the user's time is limited and concept mapping is tiring. As the designer interacts with the expert during the session, he draws the concept map. He uses key words to capture the concepts and then links the concepts together using action verbs

(McFarren,1987:131). The designer then returns to the expert and together they review the concept map. The cycle may be repeated several times as the concept map evolves. The concept map provides the decision maker with a tool to "communicate his understanding of the problem to others" (McFarren,1987:131).

Storyboards. The second step in the adaptive design process is the creation of storyboards. Storyboards are a sequence of displays that represent system functions. Good storyboards link to the concept map. However, actually linking the storyboards to the concept map is an area of active research. Furthermore, the storyboards should reflect the concepts of Representations that decision makers use to conceptualize problems, Operations on those representations, Memory aids, and Control mechanisms (ROMC) throughout. ROMC is a user-oriented and process-independent way to define the components of a specific DSS (Sprague & Carlson,1982:116).

The storyboards evolve through use of the "hook book". A hook book is a mechanism such as a note pad or computer space used to store new ideas. The designer uses the hook book while the storyboard is being developed and the user uses it when the system is operational. The hook book need only include four pieces of information: the date, the category for the entry, the idea, and the circumstances in which the idea came into being. The date indicates when the idea occurred. The category enables the user to store similar ideas together and may be added at a later date. The idea is the reason for making the hook book entry. And, finally, a one-line entry about the circumstance helps the user recall the idea.

<u>Evaluation</u>. The third step in the adaptive design process is the evaluation. Evaluation is a systematic process of judging how well the storyboards support the decision process. According to Lt Col John Valusek, assistant professor at AFIT, the designer applies Sprague & Carlson's "Four P's" approach (i.e. productivity, process, perception, and product) to evaluate and modify the storyboards before talking to a builder to determine what portion of the kernel is implementable (Valusek,1988: 108). A more formal evaluation is conducted once the DSS is functioning.

<u>Kernel Selection</u>. The last step in the Information Requirements Determination (IRD) portion of the adaptive design process is the selection of a kernel from a spectrum of possible kernels. A kernel is a focal point within the decision process.

<u>An Example of a DSS</u>

The Defense Logistics Agency Operations Research (DLA/OR) office developed a mathematical optimization model called the Commitment Dollar Allocation Model and incorporated it into an appropriate DSS (Cyrus, 1989:1). The model is part of a DSS that attempts to answer the questions "what items to buy and how much of each should be bought within constrained funding" (Cyrus, 1989:1). For example, if the Supply Automated Material Management System (SAMMS) recommended spending $50 million for certain items and the organization only has $30 million to spend, then the questions become what do we buy fully, what do we buy reduced, and what do we defer (Cyrus, 1989:3).

Similarly, the intent of this thesis is to develop an LCC model and incorporate it into a DSS that attempts to answer the questions "should an item be replaced by an improved item and if so, how should the improved item be introduced into the inventory".

Summary

This chapter defined DSS, described it, and provided an example of one. The DSS is flexible and easy to use. Three different perspectives describe DSS: the user's, the builder's and the designer's. An adaptive design approach allows DSS to evolve over time. The adaptive design methodology under investigation includes techniques such as the concept map, storyboards, and evaluation resulting in selection of a kernel. DLA/OR developed a DSS for their mathematical optimization model. In a similar manner, this thesis develops a DSS around an LCC model. Chapter three discusses the application of the concept map, feature chart, and storyboards as tools to help the designer model the decision process.

CHAPTER III

CONCEPT MAP AND STORYBOARDS

Introduction

The decison modeling process began when Capt Tim Sakulich, Analysis Branch for Material Management (HQ AFLC/MMISA), introduced the preferred spares problem to AFIT as a potential thesis topic. Capt Sakulich identified Mr. Rob Lucas from his office as the point of contact for this project and Mr. Jeff Vineyard, Spares Branch for Central Procurement Division (HQ AFLC/MMMCS), as the project sponsor. Mr. Lucas and Mr. Vineyard identified the appropriate literature to review and several individuals to interview.

Literature Reviewed. The literature identified by Mr. Lucas included applicable regulations such as AFR 800-11, 'Life Cycle Cost Management Program', AFSC/AFLC Supplement 1 to AFR 800-11, AFR 173-15, 'Economic Analysis and Program Evaluation for Resource Management', AFR 57-4, 'Modification Approval and Management', and AFLC draft Supplement to AFR 57-4 (IIRP).

Other literture identified by Mr. Lucas included AFAA Draft Report of Audit, Management of the Preferred Spares Program, (Project No. 7126118); LCC books such as 'Understanding and Evaluating Life Cycle Cost Models,' 'Life Cycle Cost Analysis Guide,' and 'Life Cycle Cost

Procurement Guide'; and Cost Analysis Strategy Assessment (CASA) Models User's Manual.

In addition to the literature identified by Mr. Lucas, Mr. Jeff Vineyard provided a comprehensive history of the preferred spare policy formulation. These historical documents consisted of letters, memorandums for record, briefing charts, talking papers, and messages. A summary of this information appears in Appendix A.

Individuals Interviewed. The individuals identified either directly or indirectly by Mr. Lucas and Mr. Vineyard appear in Table 3. These individuals provided information about budgets, CASA models, D041 data, and maintenance procedures. However, only the sessions with Mr. Lucas and Mr. Vineyard were used to develop the concept map and storyboards. The following paragraphs review the development of the concept map and storyboards, and the kernel selection.

Mr Rosenthal	AFLC/MMMCS	Spares Branch for Central Procurement Division
Ms Chauncey	AFLC/MMMCS	Spares Branch for Central Procurement Division
Lt Gooding	ASD/ALTB	Directorate of Logistics Concepts and Analysis
Mr Meitzler	ASD/ALTB	Directorate of Logistics Concepts and Analysis
Mr Kramer	AFLC/MMIRS	Recoverable Spares and War Reserve Material Branch
Mr Novak	AFLC/ACCCE	Cost Estimating Branch in Directorate of Cost Analysis
Mr Madden	AFLC/XPSM	Consultant Services Division

Table 3. Selected Individuals Interviewed.

Concept Map

The discussion of the concept map begins with the selection of the center point. The center point is the first point drawn on the concept map. All other points can be linked back to this center point.

The center points considered for this concept map were the LCC model, the modification process, and the preferred spare. The LCC model as a center point proved to be too restrictive. The concept map resulting from this center point focused entirely on the model and neglected the decision. On the other hand, beginning the concept map with the modification process in the center proved to be too broad. The preferred spare is only a small subset of the modification process. Therefore, the logical selection of a center point was the preferred spare.

As many as six major links can be seen coming out of this center point. These links include: benefits, supply entry, approval authorities, economic analysis, match old part, and initiators. Figure 1 shows the center point with the six major links.

Benefits Link. Several benefits result when the Air Force buys preferred spares. However, during the initial interview with Mr. Rob Lucas, 17 Jul 89, only the reduced cost benefit was identified. In subsequent meetings, the aspect of reduced cost was further defined as real cost savings and intangible cost savings. In addition, other benefits were identified. The aspect of benefit analysis offers the researcher another area to pursue. Some benefits such as improved reliability and

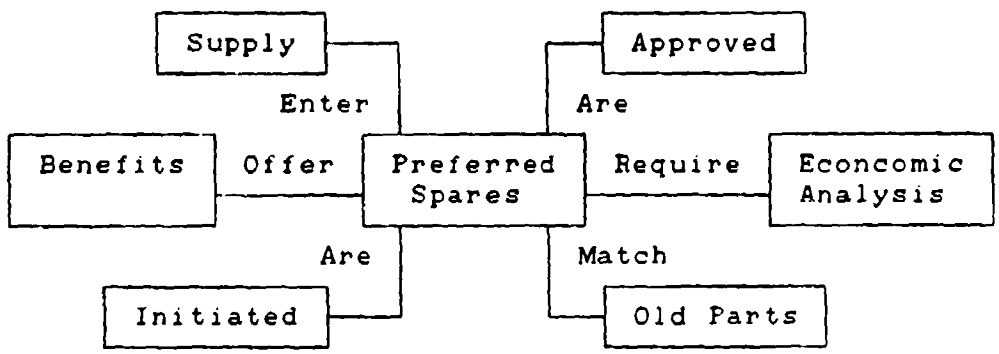


Figure 1. Aggregate Concept Map Depicting Center Point and Six Links.

maintainability save real dollars. Other benefits such as improved combat capability and safety help the Air Force realize intangible savings. Figure 2 shows these relationships.

<u>Enter Supply Link</u>. The preferred spares enter supply through normal attrition and forced attrition. Figure 3 shows these relationships. Initially, economic analysis was applied to both. However, in a follow-up interview with Mr. Jeff Vineyard on 17 Nov 89, it was understood that only the preferred spares introduced on an accelerated basis (i.e. forced attrition) would require economic analysis. Other preferred spares entering the supply

system by normal attrition would do so as a simple interchangeability and substitution (I&S) grouping and require no further analysis.

Approval Link. Furthermore, the approval and authority levels in the IIRP appeared to be valid for all preferred spares. However, the IIRP uses the AFLC

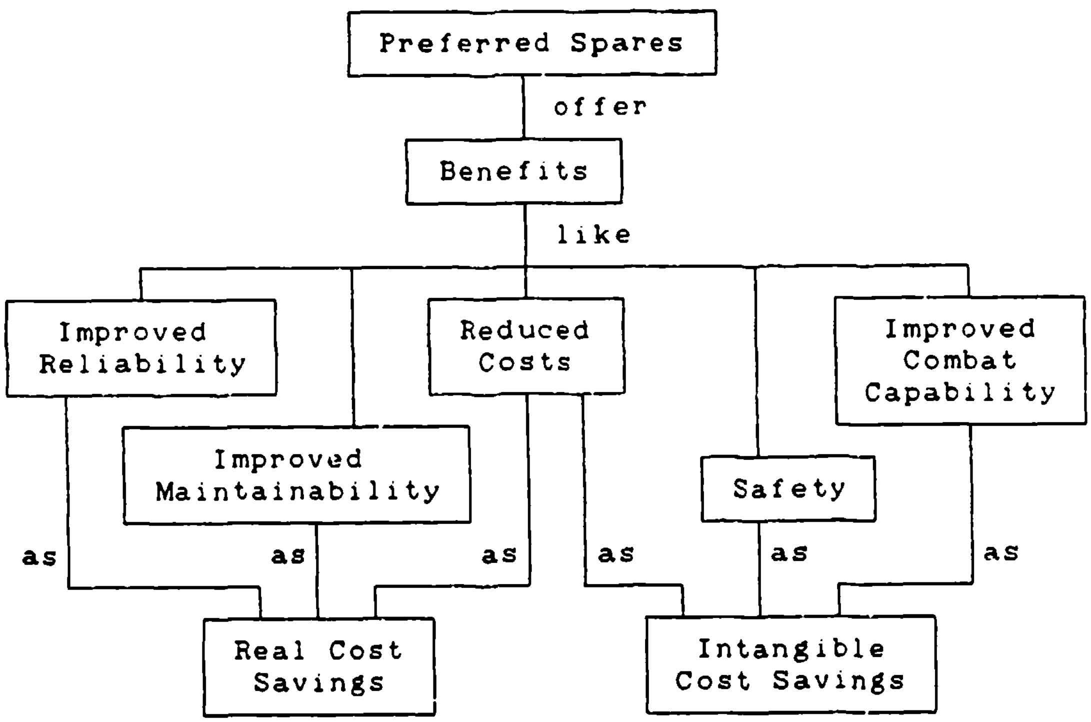


Figure 2. Benefits Link for Concept Map.

Acquisition Executive System (AES) format and only the preferred spares involving forced attrition are covered by the AES management concepts (McWilliams,1988:1). Therefore, another approval and authority level needs to be established for preferred spares involving normal attrition.

The approval and authority levels in the IIRP follow the AES format and apply to preferred spares involving forced attrition. The authority levels are based on total cost or cost per year. Table 1 on page 3 shows the approval and authority levels.

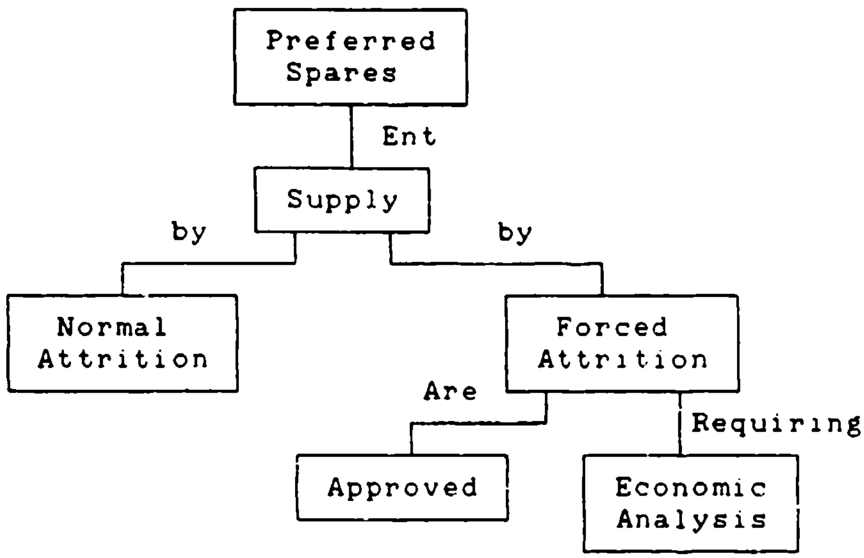


Figure 3. Enter Supply Link of Concept Map.

Economic Analysis Link. Likewise, the requirement for economic analysis, Figure 4, applies to preferred spares involving forced attrition. The economic analysis consists of a review of all colateral impacts such as infrastructure, consumables, training, technical data, support equipment, war readiness spares kit (WRSK/BLSS), automatic test equipment (ATE), and foreign military sales (FMS). The item manager uses an LCC model to understand colateral impacts, as well as to perform breakeven analysis, and to determine the appropriate acquisition strategy.

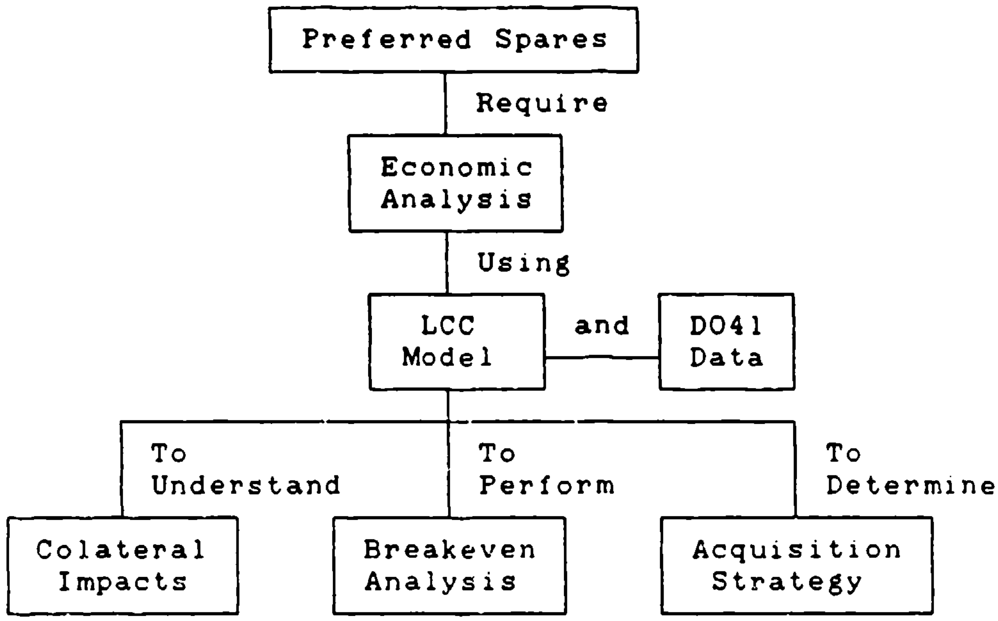


Figure 4. Economic Analysis Link of Concept Map.

Match Old Part Link. The preferred spare must match the old part in fit or function, see Figure 5, and "shall not require more than 8 clock hours or 25 manhours for installation or associated minor fit rework" (IIRP,2). The IIRP uses the installation time to differentiate a preferred spare from a modification. However, the installation time is a focus of controversy. A letter from Oklahoma City, ALC/MMM, stated, "at the point in time when the decision is made for modification or repair, installation time is, at best, an educated guess and would be subject to error and abuse" (Wheeler,1985:1). According to the IIRP, any deviation from the installation time policy would require approval from HQ AFLC/MM.

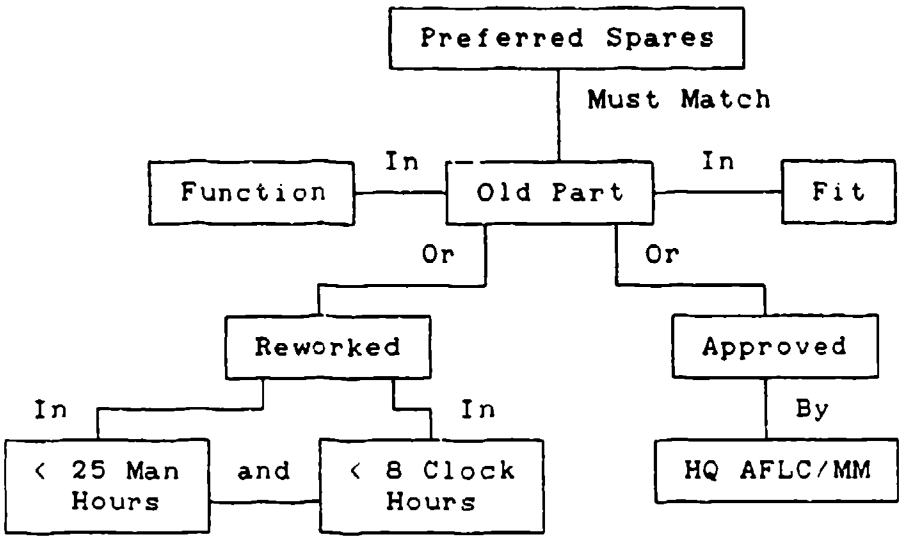


Figure 5. Match Old Part Link of Concept Map.

'Initiated' Link. Preferred spares are initiated by individuals such as item managers (IM), equipment specialists (ES), users, contractors, and senior program managers (SPM), through engineering change proposals (ECP) when parts perform poorly, costs can be reduced, technology changes, vendors vanish, or manufacturing stops. Usually, the technology changes give the preferred spares benefits over the old part. These benefits are the same benefits described earlier. Figure 6 shows the 'initiated' link of the concept map.

Summary. At the center of the concept map is the 'preferred spare' and linked to the center are: benefits, supply entry, approval authority, economic analysis, match old parts, and initiators. The concept map raises two important issues that decison makers must deal with before invoking the LCC model. The first issue concerns the amount of time required to perform any minor rework on the preferred spare. The second issue concerns the method by which the preferred spare will enter the supply system. Once the decisior maker considers these issues, he can then invoke the LCC model. The next two sections review the feature chart and the storyboards.

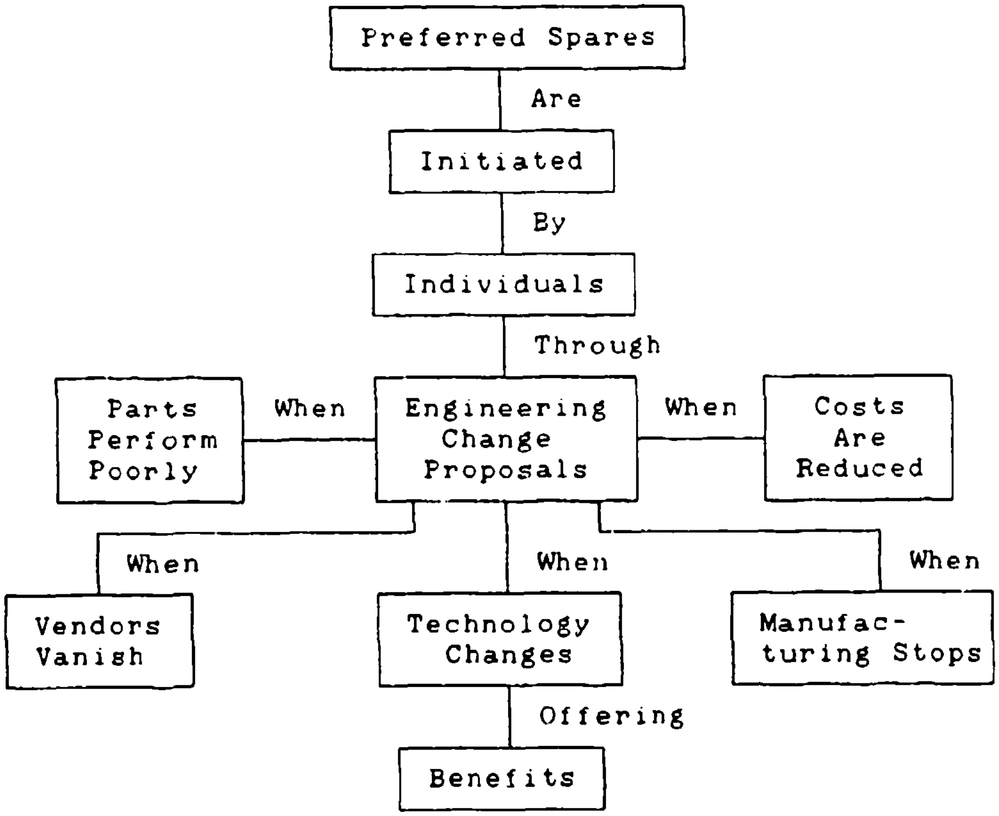


Figure 6. 'Initiated' Link of Concept Map.

Feature Chart

The feature chart, Figure 7, is "a tool for communicating the analysis for a Decision Support System" (Seagle, 1986:11). It looks like a map of the decision process and provides an overview of the storyboards. The reader is encouraged to refer back to this chart often while reading the section on storyboards to remain oriented in the decision process.

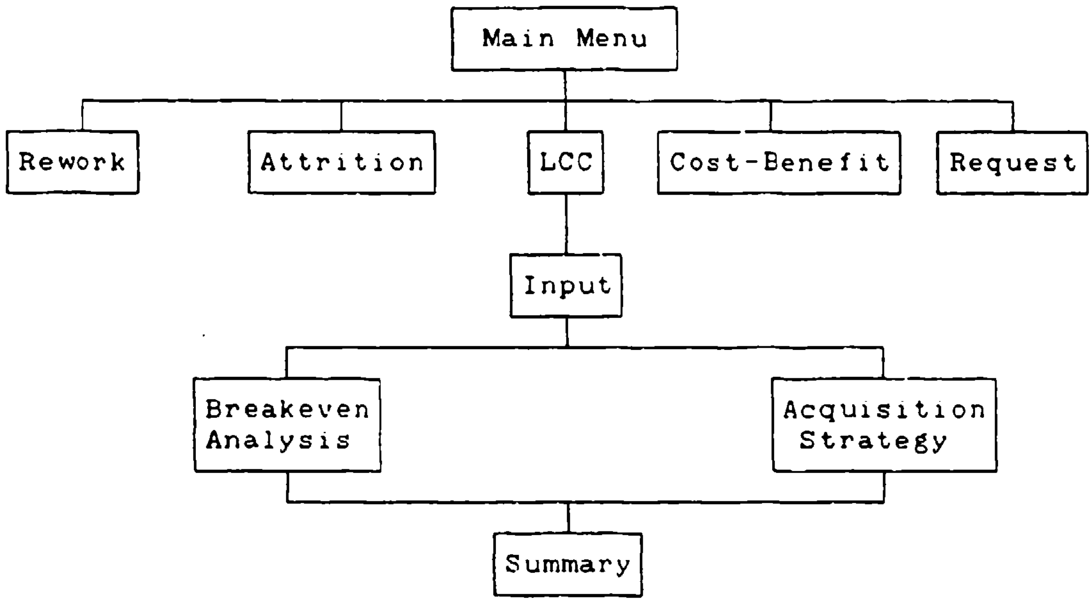


Figure 7. Feature Chart.

Storyboards

The main menu is the first menu the user sees. Since good storyboards often link back to the concept map, the first two items, rework and attrition, link back to the two issues raised by the concept map. The third item, LCC, invokes the LCC model to perform economic analysis. The fourth item, cost-benefit, helps the user analyze the link between reduced costs and benefits. The fifth item, request, helps the user fill out a 'request for approval'. Figure 8 shows the storyboard for the main menu. Numbers 1 through 6 are the 'action numbers'.

```
        DECISION   SUPPORT   SYSTEM

       PREFERRED   SPARE   LCC MODEL

    1.   Estimate Time for Minor Rework

    2.   Choose Forced or Normal Attriti

    3.   Invoke Preferred Spare LCC Mode

    4.   Cost-Benefit Analysis

    5.   Request for Approval

    6.   Quit

    SELECT ACTION NUMBER:

                            HOOK BOOK F5
                            HELP      F6
```

Figure 8. DSS Main Menu.

<u>Estimate Time for Minor Rework</u>. Action number one on the main menu calls a second menu to the screen that helps the user to determine whether the new item needs minor rework and to estimate the length of time necessary to complete the minor rework. If the time for minor rework

exceeds eight clock hours or 25 manhours, then the user classifies the action as a modification and either follows the guidelines established in AFR 57-4 or seeks a waiver from HQ AFLC/MM.

The classification of the improved item as a modification or a preferred spare depends on the installation time. However, at the time of the proposal the installaion time is uncertain and this could cause problems. According to Mr Paul Ste Marie, Deputy Director of the Space, Communications, and Common Support Directorate at HQ AFLC/CF,

> The proposed definitions or [for] modifications and preferred spares make use of installation time limits. At the time that the system improvement is proposed, the actual installation time requirements are very rough estimates. Kit proofing which will establish a definite time is not accomplished until after program approval. Any resultant change to the installation time, due to unforeseen complexity or ease of installation, could justify changing the category (Modification or Preferred Spare) of the proposed installation. This would cause previously established budget categories to change impacting, funding and program schedules. Recommend adding a restriction that would minimize this occurring, i.e., allow a reasonable percentage overrun before calling for a change from one category to another. (Ste Marie,1985:1)

This menu helps user's determine "a reasonable percentage over-run".

<u>Choose Forced or Normal Attrition</u>. Once the user returns to the main menu, he has the option of choosing another action number. Should he select action number two,

"Choose Forced or Normal Attrition", the DSS moves to a second menu to help him determine if the new item is to be introduced on an accelerated basis (i.e. forced attrition) or on a normal basis (i.e. normal attrition). If the user selects forced attrition, then the decision process continues. If not, then the process becomes a normal I&S grouping.

According to Mr Ste Marie, "a method of forced attrition and installation of the preferred spare should be identified if there is to be a measurable payoff" (Ste Marie, 1985:1). One method of forced attrition is the opportunistic maintenance concept, developed by Mr John Madden, Consultant Services Division at HQ AFLC/XPSM, for the generalized opportunistic maintenance engine simulation (OMENS). According to Mr Madden the opportunistic maintenance policy states,

> whenever an engine is removed for repair because of a problem within a module, all internal life-limited component parts of all modules should be considered for possible replacement at that time, based on how close they are to their individual maximum operating times (MOTs). This may cause the replacement of more than one subunit for each engine removal. When component parts are replaced opportunistically, they no longer cause a near-future module and corresponding engine removal for that component replacement due to reaching its life-limit. Thus, the number of future module removals for repair is greatly reduced, while the number of spare parts used is increased. (Madden, 1981:5)

Although Mr Madden applies the opportunistic maintenance policy specifically to engines, item managers could also apply the concept to improved items. Both Mr Madden and Mr Vineyard concur.

Invoke Preferred Spares LCC Models. Once the user has completed the first two items, he is now ready to invoke the LCC model from the main menu. He invokes the model by selecting action number three, 'Invoke Preferred Spares LCC Model'. The DSS calls the main menu for the LCC model, Figure 9, to display options such as parameter inputs, breakeven analysis, acquisition strategy, and the summary menu.

```
DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

INVOKE THE LCC MODEL:

1.  Parameter Inputs
2.  Breakeven Analysis
3.  Acquisition Strategy
4.  Summary

SELECT ACTION NUMBER:

                HOOK BOOK  F5
                HELP       F6
```

Figure 9. Main Menu for LCC Model.

Parameter Inputs. The user can recall the input parameters from another file or input new parameters directly. The parameter inputs for the new line replaceable unit (LRU), such as the preferred spare, are the acquisition cost and the operating and support (O&S) cost. The user needs to estimate much of this information from contractor or government sources. The parameter inputs for the old LRU are the O&S cost. The Air Force maintains this data.

```
                    DECISION SUPPORT SYSTEM

                  PREFERRED SPARE LCC MODEL

   INVOKE THE LCC MODEL:  Parameter Inputs.  Please fill
   in the cost parameters below and on the next screen.

   For the Operating and Support Cost inputs, press the
   < O&S > key located on the sub-menu bar.

       ACQUISITION COSTS                      NEW LRU

    1. System Acquisition                    _______
    2. Pre-production Engineering            _______
    3. Installation                          _______
    4. Initial Technical Data                _______
    5. Initial Item Management               _______
    6. Start Up                              _______
    7. Shipping Containers                   _______
    8. Pre-production Refurbishment          _______
    9. Initial Training                      _______
   10. Tool and Test Equipment               _______
   11. Training Devices                      _______
   12. Support Equipment                     _______
   13. Hardware Spares                       _______
   14. Spares Reusable Containers            _______
   15. New Facility Upgrades                 _______
   16. Warranty                              _______
   17. Miscellaneous                         _______

   SELECT ACTION NUMBER:


                        EDIT    F3     HOOK BOOK    F5
   O&S   F2             CANCEL  F4     HELP         F6
```

Figure 10. LCC Model Parameters for Acquisition Costs.

Figure 10 shows the screen display for the acquisition costs. The user simply puts the cost on the line next to its title and hits the < RETURN > key to submit it. The user inputs the costs directly or calculates the cost first using the appropriate equation. If the user needs help filling in the values, he selects action number, 1 through 17, and the DSS tells him what to do. Each action number corresponds to a cost element from the list. The user also uses the sub-menu keys: 1) press the F2 key, O&S, to go to the O&S cost window, 2) press the F3, edit, key to edit the data, 3) press the F4, cancel, to cancel the entire page, 4) press the F5 key, hook book, to make a hook book entry, or 5) press the F6 key, help, to get help. In a similar manner, the user inputs the O&S costs. Figure 11 shows the screen display for the O&S costs.

Breakeven Analysis. Once the model has the appropriate data, the user performs breakeven analysis to find the breakeven point. The breakeven point occurs when the old LRU cost equals the new LRU cost. The cost equation for the old LRU is equal to the sum of the cost to repair each LRU and the cost to replace condemned LRUs. The cost equation for the new LRU is equal to the sum of the cost to buy the new LRUs, the cost to repair each LRU, and the cost to replace condemned LRUs. The LCC model solves the two cost equations simultaneously to find the breakeven point. The breakeven point tells the user at what time and at what cost the old LRU cost equals the new LRU cost. In addition, the LCC model plots the two cost equations on a graph with time on the horizontal axis and cost on the vertical.

```
                    DECISION SUPPORT SYSTEM

                  PREFERRED SPARE LCC MODEL

INVOKE THE LCC MODEL:  Parameter Inputs.  Please fill
in the cost parameters below.

To return to LCC main menu, press the < LCC > key
located on the sub-menu bar.

   OPERATING AND SUPPORT COSTS             OLD LRU    NEW LRU

 1. Labor and Manpower                     _______    _______
 2. Support Equipment                      _______    _______
 3. Repair Parts and Material              _______    _______
 4. Condemnation Spares                    _______    _______
 5. Engineering Changes                    _______    _______
 6. Repair Labor                           _______    _______
 7. Consumables                            _______    _______
 8. Technical Data Revisions               _______    _______
 9. Recurring Item Management              _______    _______
10. Recurring Training                     _______    _______
11. Recurring Facilities                   _______    _______
12. Transportation                         _______    _______
13. Contractor Services                    _______    _______
14. Miscellaneous                          _______    _______

 SELECT ACTION NUMBER:


                         EDIT   F3        HOOK BOOK   F5
  LCC  F2                CANCEL F4        HELP        F6
```

Figure 11. LCC Model Parameters for Operating and Support Costs.

The LCC model summary menu, Figure 12, shows a picture of the plot.

Acquisition Strategy. The decision maker uses the LCC model to determine the best acquisition strategy. The model provides the user with a means to test different acquisition strategies. Current policy is to buy all of the new LRUs at once and to buy enough new LRUs to replace 100% of the installed items, the pipeline spares, and the safety level spares. Other scenarios include buying new LRUs to replace only a percentage of the old LRUs or buying a full compliment of new LRUs over a certain time period (i.e. 25% per quarter for four quarters). In addition, the model provides a detailed breakout of the cost by fiscal year. The acquisition cost storyboard appears in Appendix B and the model appears in Appendix C.

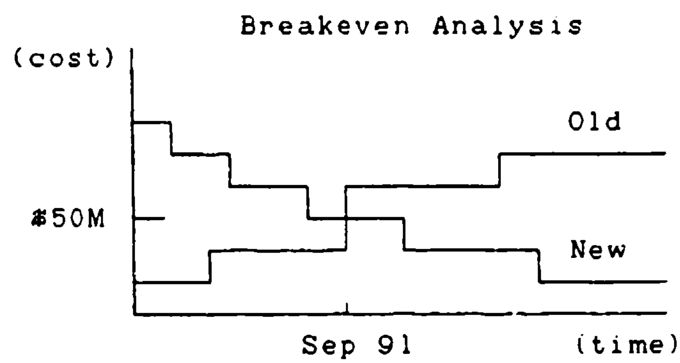
Summary Menu. The decision maker uses the summary menu to review results and to perform sensitivity analysis. The results from the breakeven analysis appear on a graph. Then, the user can play "what if" games and watch the graph change. Figure 12 shows the summary menu.

Cost-Benefit Analysis. Action number four on the DSS main menu calls a second menu to help the user identify the benefits such as reduced costs, better combat capability, improved reliability, improved maintainability, and safety associated with both the new LRU (i.e. preferred spare) and the old LRU. The purpose of the analysis is to determine which alternative provides the most benefits at the least cost. The DSS helps user develop a method, such as utility theory, to quantify the benefits. Then, the user takes the costs determined by the LCC model and divides the benefits by the cost to determine the benefit-cost ratio.

DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

INVOKE THE LCC MODEL: Summary.



1. Unit Cost
2. Condemnation Rate
3. MTBF or MTTR
4. Acquisition Strategy
5. Discount Rate

SELECT ACTION NUMBER:

PRINT	F1			HOOK BOOK	F5
MAIN	F2	QUIT	F4	HELP	F6

Figure 12. LCC Model Summary.

Request for Approval. Action number five on the DSS main menu calls a second menu that identifies the proper approval and authority levels, see Table 1 on page 3, and helps the decision maker write the request for approval. The request for approval is similar to the form currently being used by HQ AFLC. The form includes facts about the preferred spare, a description of what is to be accomplished, and the results of the cost analysis.

Kernels

Several potential kernels were identified in this decision process: 1) estimating the minor rework time, 2) selecting the method of attrition, 3) determining the breakeven point, 4) identifying the appropriate acquisition strategy, and 5) relating benefits to cost. Since it became the author's intent to incorporate an LCC model into an appropriate DSS, the remainder of this thesis will concentrate on the breakeven point and acquisition strategy in order to answer the questions "should an item be replaced by an improved item, and if so, how should the improved item be introduced into the inventory". These kernels are important for:

* Estimating the LCC for the preferred spare;
* Selecting the appropriate acquisiton strategy;
* Determining the breakeven point;

The other kernels are also important to the decision process, but will have to be the subject of future research.

Summary

This chapter focused on the application of concept mapping, feature charting, and storyboarding. The discussion began with the identification of two experts who could help in the creation of the concept map and storyboards. The process resulted in the identification of several kernels. Two kernels, the breakeven point and acquisition strategy are reviewed further because of their close association with the LCC model. The other kernels are the subject for future research. Chapter four discusses the validation of the CASA model, a systematic evaluation of the model equations, and the creation of a simple LCC model using Lotus 1-2-3 spreadsheet capability.

CHAPTER IV

THE PREFERRED SPARES LCC MODEL

The Preferred Spares LCC model uses equations from the CASA model because the CASA model is a valid LCC model and defines the cost elements required by the IIRP. The following paragraphs review the development of the Preferred Spares LCC model on the Lotus 1-2-3 spreadsheet. Specifically, the discussion covers the topics on validation of the CASA model, evaluation of the model equations, and development of the Preferred Spares LCC model from those equations.

Validation of the CASA Model

On 28 Feb 1989, Col David Olsen, Deputy Comptroller for Cost and Economics at HQ USAF, sent a letter to HQ AFLC/ACC and HQ AFSC/ACC on the subject of model validation. According to Col Olsen, the Air Force Cost Analysis Improvement Group (CAIG) could not accept the results of non-validated, unknown models (Olsen, 1989:1). Furthermore, he encouraged designers of cost models to cross-check the new model with a proven model (Olsen,1989:1).

In response to this letter, the Directorate of Logistics Concepts and Analysis (ASD/ALT) told Lt Ross Gooding to validate the CASA model. He validated the CASA models by comparing them to the widely used Life Cycle Cost H (LCCH) model. He used sample data from the LCCH user's manual as input to both models and then compared the respective outputs (Gooding, 1989:1). Lt Gooding noticed that the models generated similar results in all areas except hardware spares. According to Lt Gooding, the CASA model underestimated the cost for hardware spares by 32% (Gooding, 1989:14). However, Mr Tom Meitzler, also from ALT, noticed that the difference could be explained by the way the models handled certain data inputs (Meitzler,1989).

Evaluation of the Model Equations

The evaluation of the CASA model consisted of a systematic study of the model equations for both the acquisiton cost and the O&S cost. The cost elements were put into three categories: 1) input directly, 2) input after simple calculations, and 3) input after more complicated calcu-lations. The remainder of the discussion highlights the more complicated calculations.

Acquisition Costs. The CASA model defines the acquisition cost as costs associated with the design, development, and the procurment of systems and support items necessary to make the system operational (CASA,1986: 3-4). The model calculates each cost annually. Certain costs are put into the model directly. Others require simple calculations such as multiplying the unit cost by the number of units. Other costs require more complicated calculations. Table 4 shows the aquisition costs. Then this section reviews those costs requiring complicated calculations.

I. Input Directly:

1. Production Tooling and Test Equipment Cost
2. Production Start-up Cost
3. Pre-Production Engineering Non-Recurring Cost
4. Warranty Price
5. Miscellaneous Acquisition Cost

II. Input After Simple Calculations:

1. System Shipping and Storage Containers Cost
2. Pre-Production Units Refurbishment Cost
3. Installation Cost
4. Spares Reusable Containers Cost
5. Technical Data Cost
6. Training Devices Cost
7. New or Modified Facilities Cost

III. Input After More Complicated Calculations:

1. System Acquisition Cost
2. Support Equipment Cost
3. Hardware Spares Cost
4. Initial Training Cost

Table 4. Acquisition Costs According to Method of Input.

System Acquisition Cost. The total system acquisition cost equals the number purchased times the unit cost times an adjustment factor. The number purchased equals the quantity purchased raised to the rate factor (RFAC) power times the cumulative total number purchased raised to the quantity factor (QFAC) power. The user supplies the rate slope showing the effect of yearly build quantity on system cost for the RFAC formula and the quantity slope showing the effect of total quantity build on system cost for the QFAC formula. The user also supplies an adjustment factor to account for inflation and the effect of "learning".

<u>Support Equipment Cost</u>. The support equipment (SE) cost equals the number purchased times the unit cost. The model begins with no SE. It then calculates the number of SE required during the first year. This number includes SE availability, SE utilization, and the average number of maintenance actions (MA) per month. Embedded within the MA formula is the MTBF growth factor. The user has the option to use Duane reliability growth for this growth factor. The Duane reliability growth factor is "the best known and most widely used method of modeling reliability growth" (CASA, 1986:4-3). The model calculates the SE cost for the first year by multiplying the SE quantity with the unit cost. Then, the model repeats the process in the second year. If the SE quantity in the second year is equal or less than the SE quantity for the previous year, then no additional SE are required. Otherwise, the difference is added to the SE quantity and reflected as a cost in year two. The process continues throughout the life of the system.

<u>Hardware Spares Cost</u>. The method to calculate

the cost for hardware spares is similar to the one for SE. The process begins with no spares in the inventory. During the first year, the model uses the Poisson distribution to calculate the spares required to satisfy the part's demand rate. These spares are added to the inventory. In the second year, the model calculates the spares required to support the maximum number of systems in the inventory. If this quantity is less than or equal to the existing spares inventory, no additional spares are required. If this quantity is greater than the existing spares inventory, the difference is added to the spares inventory and the additional cost for hardware spares appears in year two. This process repeats itself for each year of the life cycle.

Initial Training Cost. The initial training (IT) cost is equal to the sum of the development cost (DC), the instructors cost (IC), and the trainees cost (TC). The DC is the number of course hours times the cost per hour. The IC is the product of the number of course hours, the number of instructors required, and the hourly instructor labor rate. The TC considers the number of trainees, the class hours, the average trainee labor rate, the number of days, the per diem, and the average cost for transportation.

Operating and Support Costs. The CASA model defines the O&S cost as costs associated with the operation, the maintenance, and the support of all systems and support equipment during the equipment life (CASA,1986:3-28). Like the acquisition costs, the model computes O&S cost annually. Table 5 shows the O&S cost in one of three categories.

Recurring Training Cost. The recurring training cost is equal to the product of the number of maintenance personnel required at each location, the maximum number of locations, the annual turnover rate of maintenance personnel, the number of hours required to train new personnel, the average hourly labor rate, and the number of months the system operates. The product is divided by 12 to reduce the turnover rate by the appropriate amount. The number of maintenance personnel required at each location equals the

I. Input directly:

1. Engineering Changes Cost
2. Miscellaneous O&S Costs

II. Input After Simple Calculations:

1. Operation Labor Cost
2. Repair Labor Cost
3. Support Equipment Maintenace Cost
4. Repair Parts and Materials Cost
5. Repair Consumables Cost
6. Condemnation Spares Replenishment Cost
7. Technical Data Revisions Cost
8. Recurring Facilities Cost
9. Recurring Item Management Cost
10. Contractor Services Cost

III. Input After More Complicated Calculations:

1. Recurring Training Cost
2. Transportation Cost

Table 5. Operating and Support Cost According to Method of Input.

maintenance man-hours per month divided by 160 and rounded to the nearest whole integer. The model adds a development cost to the recurring training cost the first year there is a need for maintenance personnel.

Transportation Cost. The model calculates the transportation cost (TC) for each item and sums them to get the total TC. If the item is repairable, then the TC includes the cost to transport the item between its removal level and its primary repair level (TRIPS). If the item is not-repairable-this-station (NRTS), then the TC includes the cost to transport the item between its repair level and its NRTS repair level (TPNRTS). The TRIPS considers the ex- pected number of demands and two trips per demand. The TPNRTS equals TRIPS times NRTS. Other associated costs include the cost per pound for each item and the cost for packing and handling.

The LCC Model on the Lotus 1-2-3 Spreadsheet

This section reviews the process to convert the cost equations from the CASA model to the Lotus 1-2-3 spreadsheet. Specifically, the discussion includes topics on the spreadsheet methodology, the model assumptions, the new equations for the spreadsheet, and the differences between the new equations and the CASA model equations.

The Spreadsheet Model. The spreadsheet model was selected for several reasons:

1. The spreadsheet model is a good prototype model. A prototype model is a real, working, and usable model built economically and quickly with the intention of being modified (Cerveny, Garrity, and Sanders,1985:52).

2. The spreadsheet model is an easy model for user's to understand because the data structures are visible and the results are plotted on a graph.

3. The spreadsheet model supports 'what if' analysis: 1) what if the unit cost of the preferred spare changes, 2) what if the condemnation rate changes, 3) what if the number bought changes, 4) what if the acquisition strategy changes, and 5) what if the discount rate changes. By changing one number the user can quickly see the impact on LCC.

Some General Assumptions. The CASA model calculates the LCC for many LRUs and shop replacement units (SRUs), considers three maintenance levels, and considers each base individually. The LCC spreadsheet makes three simplifying assumptions. First, the model assumes one improved item (i.e. LRU or SRU) replaces one spare at a time. This assumption is valid since the model is intended to help the user compare single items. Second, regarding maintenance levels, this model assumes there is a place to operate the system and another place to repair parts that fail. This assumption could cause the model to underestimate costs such as transportation, SE, and hardware spares. And third, the model assumes all costs occur at a single operating location (i.e. the base).

<u>The Acquisition Cost Equations</u>. The acquisition cost equals the system investment cost, the hardware spares cost, and the SE cost. The system investment cost is the sum of the costs for 1) production tooling and test equipment, 2) production start-up, 3) system acquisition (number of items * unit cost), 4) system shipping and storage containers (number of containers * average unit cost), 5) pre-produc-tion engineering, 6) pre-production units refurbishment (number of units * average unit cost), 7) installation (number of systems * cost per system), 8) spares reusable containers, 9) technical data (number of pages * [average cost per page to develop + number of copies * average cost per page to prepare a finished printed document]), 10) initial training (development cost + instructor cost + trainee cost), 11) training devices (number of devices * average unit cost), 12) new or modified facilities (number of square feet * cost per square foot), 13) initial item management (number of new items * cost per item), 14) miscellaneous aquisition costs, and 15) warranty price.

The hardware spares cost equals the number of spares times the cost for each spare. The user estimates the required number of spares or uses this formula:

$$DEMANDS = (NUMSYS)*(NUMINSYS)*(OPERHRS)/(MTBF) \quad (1)$$

where

DEMANDS = expected number of demands (num of spares),
NUMSYS = number of systems,
NUMINSYS = number of items in each system,
OPERHRS = expected number of system operating hrs/yr,
MTBF = mean time between failures in hours.

The LCC model assumes that the base requires a new spare everytime an item fails. If this is not a good assumption, then the user should input the necessary hardware spares manually and use the number of DEMANDS to help him.

The SE cost equals the number of SE times the cost for each SE. Once again, the user either estimates the required number of SE or uses the following formulas:

$$SEUTIL = (DEMANDS)*(AVGHRS) \quad (2)$$

$$SE = (SEUTIL)/(SEAVAIL) \quad (3)$$

where

SEUTIL = total hours utilization per year,
DEMANDS = expected number of demands,
AVGHRS = average number of hrs/maintenance action,
SE = number of support equipment,
SEAVAIL = average available hours per SE per year.

The O&S Cost Equations. The O&S cost for the spreadsheet model includes costs for labor, SE replacement, recurring training, repair parts and materials, condemnation spares, technical data revisions, transportation, recurring facilities, recurring item management, contractor services, engineering changes, and miscellaneous O&S costs.

The labor cost includes cost of the operation labor and the repair labor. The operation labor cost equals the hourly labor rate for the operator times the total number of operating hours. The repair labor cost equals the hourly labor rate for the maintenance personnel times the total number of repair hours. The repair labor cost considers the number of maintenance hours and the mean time to repair (MTTR) each item.

The spreadsheet model uses the SE replacement cost instead of using the SE maintenance cost. Often in O&S cost estimating, the SE maintenance cost equals zero. According to Maj Thomas May, Directorate of Cost Analysis (ASD/ACCL),

> support equipment and their components are also periodically returned to the depot for overhaul and repair. This category accounts for these costs and includes both common and peculiar support equipment. However, it is typically treated as zero. An adequate data base has not been developed to support an estimate for base level aircraft support equipment and the repair of depot level support equipment is included in the depot maintenance overhead already priced to the other elements. (May,1982:9-6)

The SE replacement cost, on the other hand, equals 6 percent of the total acquisition cost for SE (May,1982:11-3).

The recurring training cost is the cost associated with instructing new maintenance personnel. The number of new maintenance personnel equals the total number times the turnover rate. This number is then multiplied by the training cost. The AFR 173-13 publishes training costs and turnover rates.

The repair parts and materials cost equals the number of maintenance actions times the average material cost per repair. Current cost estimating relationships (CERs) exist at ASD/ACCL to help the user determine the average material cost per repair. A CER is a mathematical equation that relates characteristics of an item to a desired element of cost (May,1982:3-1). This cost includes costs required for consumables such as alcohol, cleaners, and swabs.

The condemnation spares are those items procured to maintain a required stock level as items are lost to the supply system due to condemnation (May,1982:10-2). The cost to buy these items is equal to the number purchased times the unit cost. The number purchased equals the total number times the portion of failures expected to be condemned. The D041 data base is a good source of condemnation spares data (May,1982:5-10).

The technical data revisions cost equals the number of pages of technical data that will be revised times the cost to develop technical data revisions.

The transportation cost equals the number of trips times the respective cost. The trips include from the removal level to the repair level and from the repair level to the NRTS level. The associated costs are the cost per pound and the cost for packing and handling.

The remaining costs are 1) recurring facilities cost (total number of square feet in the facility * annual cost per square foot), 2) recurring item management cost (cost for the new parts introduced to the inventory + the cost for the stocked items already in the inventory), 3) contractor services cost, 4) engineering change cost, and 5) miscellaneous O&S costs.

<u>Cost Equation Differences</u>. The CASA model has detailed cost elements and complicated equations. The Preferred Spares LCC model, on the other hand, is quite

Cost Element	Preferred Spares Model	CASA Model
System Acquisition	(number * unit cost)	includes rate and quantity factors for system cost determination.
Support Equipment	(number * unit cost)	includes reliability growth option (i.e. Duane growth).
Hardware Spares	(number * unit cost)	uses Poisson distri -bution function to determine required spares quantities.
Labor	does not include re-test okay.	includes retest okay.
SE Maintenance	estimates replace-ment cost equal to 6% of SE acq cost.	(avg unit cost * a fraction of the cost of the SE).

Table 6. Significant Differences Between the Preferred Spares LCC Model and the CASA Model Equations.

simple. Some of the differences between the models are explained by the simplifying assumptions mentioned earlier. Others appear in the equations themselves. Table 6 highlights some of the significant differences between the model equations.

Spreadsheet Methodology.

Inputs. The user provides inputs for the model such as: 1) unit cost, 2) MTBF, 3) condemnation rate, 4) repair cost, 5) average operating hours per year, 6) number of items per operating system, 7) number of operating systems, 8) discount factor, and 9) first year of the LCC.

Acquisition Strategy. Next, the user develops an acquisition strategy based on the number of new LRUs acquired each year for installation. The model calculates the expected number of hardware spares to support the new LRUs and the number of LRUs expected to be condemned. The model subtracts the sum of the new LRU installed from the old LRU total. The model assumes that the hardware spares for the new LRU will support only the new LRUs installed.

Acquisition and O&S Costs. The user inputs the cost elements for acquiring the new LRU. The miscellaneous cost element provides the user with the option to override other cost elements or to add cost elements peculiar to the study. The spreadsheet sums the cost elements for each year, applies the discount factor selected by the user, and calculates the cumulative total acquisition cost. The user also inputs the cost elements for the new LRU and the old LRU O&S costs. The miscellaneous cost element serves a similar function and the spreadsheet performs similar calculations.

Discount Factors. The discount factor attempts to consider the time value of money. The LCC model uses a discount rate of 10% because the Office of Management and Budget (OMB) recommends using it (AFR 173-15,1988:9). The LCC model user can also select a discount rate of 7 or 5 percent in order to see whether the decision changes at the lower rate. The 10, 7, and 5 percent tables were taken out of AFR 173-15, "Economic Analysis and Program Evaluation for Resource Management". The model uses tables so the user can see the actual numbers of the various discount rates. Each discount rate table uses a mid-year discount rate because AFR 173-15 recommends using it when the precise timing of outlays is unknown. The mid-period minimizes the maximum potential error (AFR 173-15,1988:21).

Speadsheet Model Validation. The Preferred Spares LCC model was validated using data from an LCC study for the F-15 A/D Ring Laser Gyro (RLG) Inertial Navigation Unit (INU). Oklahoma City, ALC performed the study to determine if the Air Force should replace the current navigation system, LN-31, with the new RLG. Data included the acquisition cost for the new RLG and the O&S cost for both navigation systems. However, the data for the RLG came from two different sources. The Air Force intended to buy half of the preferred spares from Honeywell Corporation and the other half from Litton Corporation.

The data from the two sources could be averaged or kept distinct. For the purpose of validating the model, the author kept the data distinct by: 1) copying the new LRU inputs to an adjacent column, 2) labeling the new LRU columns A and B, and 3) making minor adjustments to certain formulas in the model. Certain cost elements were set to zero because the data was missing. Extra data, not accounted for by the model, was included in the miscellaneous cost element category.

The Preferred Spares LCC model used the actual acquisition strategy of buying 53 RLGs the first year, 654 RLGs the second, and 109 RLGs the third. The model also used a discount rate of 10%. The user could change the acquisiton strategy or discount rate to perform sensitivity analysis. The results were plotted on a graph and compared to the actual Air Force study. Appendix D shows the data and the graphs. The graphs plot the LCC in constant and discounted dollars for each year. The graphs also plot the net cost savings (or losses).

The Preferred Spares LCC model results were consistent with the results of the actual Air Force study. The break-even points were similar and the yearly LCC were almost identical. Table 7 shows the cost differences between the AF study and the LCC model (assuming a 10% discount rate).

FY	Air Force Study	LCC Model	% Difference
Losses:			
FY88	-8,913,209	-8,913,207	2.24 E-05
FY89	-64,936,834	-64,936,654	2.77 E-04
FY90	-63,662,783	-63,662,553	3.61 E-04
FY91	-31,937,641	-31,937,410	7.23 E-04
FY92	-22,445,418	-22,445,280	6.15 E-04
FY93	-13,940,756	-13,940,614	1.02 E-03
FY94	-7,007,773	-7,007,625	2.11 E-03
FY95	-742,634	-742,482	2.04 E-02
Savings:			
FY96	4,952,714	4,952,868	3.12 E-03
FY97	10,130,768	10,130,926	1.56 E-03

Table 7. Old/New LRU Cost Differences between AF Study and LCC Model (in discounted dollars 10%).

Summary

This section discussed the development of the Preferred Spares LCC model from the CASA model equations. The equations were converted to a spreadsheet and validated using actual Air Force data. The final chapter reviews the results, conclusions, and recommendations.

CHAPTER V

RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter discusses the overall findings and results obtained from developing an LCC model and incorporating it into a DSS that attempts to answer the questions "should an item be replaced by an improved item and if so, how should the improved item be introduced into the inventory". The recommendations for future research focus on enhancing the DSS.

Results

The primary purpose of developing this LCC model was to provide the item manager with a tool to perform economic analysis to determine the breakeven point and acquisiton strategy. As a management tool, the use of the model has several positive results:

1. Foremost is the fact that the item manager can perform economic analysis on preferred spares quickly. In today's environment, the value of a cost estimate can be lost because of the long process required.

2. Furthermore, the item manager, the equipment specialist, or other model users have real-time information at their finger tips regarding the preferred spares acquisition process. The user can test different

acquisition strategies, plot the results, and perform "what if" sensitivity analysis. Once the model is available, the user can get the data from D041 and AF regulations.

3. Then, at a later time, the Preferred Spares LCC model could be incorporated into a DSS that helps item managers make decisions concerning minor rework, attrition, cost-benefit analysis, and the proposal.

The use of the Preferred Spares LCC model also has some negative results:

1. The model is large. It's easy to become disoriented when the cost element or year do not appear on the computer screen.

2. Some model assumptions over-simplify the process. For instance, the model assumes the number of hardware spares equals the number of demands.

3. The model does not supply the user with an optimum acquisiton strategy.

Conclusions

This thesis explored the topic of preferred spares acquisition. The Air Force buys preferred spares to make hardware improvements to weapon systems. However, a recent Air Force audit revealed that the Air Force needed a tool to help item managers perform economic analysis when considering preferred spares decisions. To accomplish this, an LCC model was developed to be incorporated into an appropriate DSS.

The DSS was selected as a methodology for the problem formulation. Certain techniques such as the concept map, the feature chart, and the storyboards were useful in understanding the decision process and in identifying the kernel. The concept map was helpful for: 1) recognizing the need to do a cost-benefit analysis, 2) seeing the link between acquisition strategy and the breakeven analysis, and 3) raising issues concerning minor rework and attrition. The storyboards linked well to the concept map and captured the decision process. The storyboards allowed the modeler to see where the model fit in the decision process, and helped him to keep the model 'simple'.

The Preferred Spares LCC model is a Lotus 1-2-3 spreadsheet developed from the cost equations in the CASA model. The CASA model is a valid LCC model and considered the same cost elements required by the IIRP. The spreadsheet was selected as the model for several reasons: 1) the model could be built quickly and economically with the intension of being modified, 2) the user could easily understand the model, 3) the spreadsheet could plot graphs for breakeven analysis, and 4) the spreadsheet has the ability to support 'what if' analysis.

Once the Preferred Spares LCC model becomes available, the item manager will have a model to calculate preferred spares LCC as required by the IIRP. Some model characteristics include:

* This model is easy to use. It requires only the knowledge necessary to operate the Lotus 1-2-3 spreadsheet and does not require the item manager to becomes an LCC analyst.

* The model results are easy to understand. All of the data structures are clearly visible and the results are plotted on graphs.

* Most of the data is available from D041, AF regulations, or contractor sources. Any data left out by the model can be added to the miscellaneous cost element category. Any data not available can be set to zero by the user and noted in the report.

* The model is quick. It takes the user only a few minutes to enter the data and the results are instantaneous.

Recommendations

This section makes recommendations for future research. Specifically, the discussion covers the topics of screening intervals, optimization, other recommendations, a roadmap for implementing the DSS, and remarks.

Screening Interval. One method to introduce the improved item on an accelerated basis (i.e. forced attrition) is to apply Mr John Madden's opportunistic maintenance policy. The DSS could help item managers develop screening intervals to change the policy for a specific improved item. If a part's age falls within the screening interval, then the maintenance personnel remove the part opportunistically (Madden,1981:6). The user trys the screening interval in the LCC model to test its effectiveness. To be effective, a "screen should save on maintenance costs and reduce removals" (Madden,1981:2).

Optimization. Presently, the Preferred Spares LCC model cannot select an optimal acquisition strategy. However, the model is useful because 1) the method and the justification are easy for the item manager to follow, 2) the model provides insights into the problem not obvious before, and 3) the model has the potential to give better answers than were obtained before.

The LCC model can become an optimization model by applying the mathematical technique called dynamic programming. According to Hillier and Lieberman, co-authors of the book Introduction to Operations Research, dynamic programming "provides a systematic procedure for determining the combination of decisions that maximizes overall effectiveness" (Hillier and Lieberman,1980:266). One recommendation is to approach the problem as a multistage decision process. Each year would represent a single stage. The objective would be to pick an acquisiton strategy that minimizes the cost difference between the new and old LRU for stages prior to the breakeven point and maximize the cost difference for stages after the breakeven point.

Other Recommendations. Other recommendations for future research include:

1. Develop a method to categorize nonmonetary costs and benefits and to compare them within categories.

2. Assess the budgetary impact of changing a preferred spares action to a modification (or changing a modification to a preferred spares action) at various points during the acquisition process.

3. Assess the impact of the Preferred Spares LCC model assumptions on the economic analysis.

4. Incorporate maintenance levels in the Preferred Spares LCC model to test two verses three level maintenance concept for individual LRUs or SRUs.

5. Establish an approval and authority level for preferred spares involving normal attrition.

Roadmap for Implementing the DSS. This section outlines the procedures necessary to implement the DSS for the Preferred Spares LCC model. The steps are as follows:

1. Use the prototype LCC model to study actual Air Force preferred spares data in order to learn what the important cost elements are. Improve the LCC model based

on observations made in step one.

2. Send the LCC model to Air Staff, the ALCs, and other HQ AFLC offices for comments. Make necessary adjustments and send the model to the General Accounting Office for an audit check.

3. Incorporate the LCC model into the prototype DSS and send the DSS to Air Staff, the Air Logisitic Centers, and other HQ AFLC offices for comments.

4. Implement the prototype DSS.

Remarks. This thesis showed: 1) the essence of a complex logistics problem could be captured using methods such as concept mapping and storyboarding, and 2) the spreadsheet could be used as a prototype LCC model. As a result of this thesis, the Air Force has: 1) a working prototype LCC model for economic analysis of the preferred spare acquisition process, and 2) the design of the major components of a DSS for the preferred spare acquisition process. The DSS design focuses on the LCC portion of the preferred spare problem.

APPENDIX A:

A Short History of the Preferred Spare Policy

I. Introduction

The following paragraphs will review the history of the preferred spare policy. Specifically, the discussion covers the need for a policy, the definition of a preferred spare, and the regulations.

II. Need for a Policy

This section reviews the need for a preferred spares policy. The discussion includes problems with the Configuration Control Board (CCB) process, confusion about replenishment spares funding, a desire to speed up the overall product improvement process and a need for additional Air Force guidance. The CCB is an approval forum for configuration changes by item replacement. In a message, 201801Z Mar 85, to several Air Force organizations including HQ USAF/ LEX/LEY, HQ AFLC/MM, and HQ TAC/LG, the Warner Robins ALC identified three problems with the CCB process (Slade,1985:3-4):

1. The Air Force requires BP11 funds for modifications and component reliability improvement.

However, after the Air Force allocates BP11 funds to modifications, very little money is left for component reliability improvement.

2. The Air Force uses a priority system to distribute limited BP11 funds among competing component reliability improvement options. This system tends to favor simpler systems with fewer requirements instead of the more complicated systems with many requirements.

3. The BP11 funds allocated for component reliability improvement take a long time to get to the ALCs.

The Air Force was also aware of the confusion concerning the use of replenishment spares funds. A Future Look 84 Tiger Team review of AFLC's effectiveness to improve weapon system reliability, maintainability, and availability revealed various degrees of confusion among, as well as within, the ALC's concerning the use and flexibility of replenishment spares funds (Loyd,1985:1).

Furthermore, the Air Force was looking for ways to speed up the overall product improvement process. HQ USAF/LEY sent a message, 231610Z Sep 85, to HQ AFLC/MM asking them to develop a comprehensive plan for increasing the use of depot maintenance repair and decreasing the use of modifications (Maynor,1985:1).

On 9 Oct 85, HQ AFLC wrote a memorandum for record on the subject preferred spares verse modifications. The memorandum referenced the HQ USAF/LEY message, 231610Z Sep 85, and stated,

> essentially, the goal is to find ways to speed up the overall product improvement process. Although the LEY message specifically addresses repair actions, we have expanded this to include preferred spares. (LaGrone,1985:1).

In response to Air Staff's request, HQ AFLC/MM sent a letter, dated 16 Oct 85, to Sacramento ALC/MM asking PACER LAB to develop a plan. The plan would include: (1) new definitions for the terms modification, preferred spares, and depot maintenance repair, and (2) develop and implement a strategy to include changes in policy and procedures (Maynor,1985:1).

On 12 Dec 85, HQ AFLC/MM briefed HQ USAF/LEYY on definitions, management, funding, and associated issues regarding preferred spares. It was agreed upon at the meeting that "additional AF guidance would be developed to define the preferred spare and maintenance action methods of product improvement" (Jones,1985:1).

As a result of this meeting, HQ AFLC became the OPR for 7 action items (Jones,1985:2):

1. Determine proper way of allocating costs for data, etc., for preferred spares method (e.g., with unit costs or separate line item) and proper funding account to use.

2. Draft policy on "minor fit" changes using preferred spares method.

3. Issue interim waiver policy on "minor fit" changes using preferred spares.

4. Determine proper method for managing and funding depot maintenance action kits.

5. Determine proposed support thresholds for support equipment purchase for preferred spares method.

6. Determine thresholds for CCB/HQ USAF approval.

7. Draft proposed configuration item (CI) definition/ policy changes.

III. Defining a Preferred Spare

HQ AFLC/MMM sent a letter, dated 21 Nov 85, to each ALC and another letter, dated 25 Nov 85, to other offices within AFLC. The letters tasked the recipients to comment on the new definitions for the terms modification, preferred spare, and depot maintenance repair. At the time the letter was written, the definition for the term preferred spare was

> an individual part, subassembly, assembly supplied for the maintenance or repair of systems or equipment that has beneficial qualities over an existing or alternate spare part and does not affect form, fit or function of the configuration item. (Murdock,1985:2)

The proposed addition/change to this definition pertains specifically to the use of the preferred spare in lieu of a modification. The proposed change said a preferred spare is

> a changeout of recoverable or expense items that does not affect form, fit or function of the affected configuration items or affects form only or form and fit if installation of the configuration item does not exceed 8 clock hours or 25 total manhours. (Murdock,1985:3)

The Oklahoma ALC/MMM replied on 4 Dec 85. They did not agree with using installation time to distinguish between a modification and a repair. The letter stated, "at the point in time when the decision is made for modification or repair, installation time is, at best, an educated guess and would be subject to error and abuse" (Wheeler,1985:1).

Likewise, Ogden ALC/MMM did not agree with using the installation time either. In a letter, dated 6 Dec 85, they stated, "this appears to limit such replacements to those that could be accomplished in the field with organizational / intermediate level maintenance personnel" (Ewing,1985:1).

Furthermore, HQ AFLC/CF cautioned HQ AFLC/MMM on using installation time limits to distinguish between modifications and preferred spares. Their letter, dated 9 Dec 85, stated,

> any resultant change to the installation time, due to unforseen complexity or ease of installation, could justify changing the category (modification or preferred spare) of the proposed installation. This would cause previously established budget categories to change impacting, funding and program schedule. (Ste Marie,1985:1)

They also said to solve this problem, ease the restrictions. For instance, "allow a reasonable percentage overrun before calling for a change from one category to another" (Ste Marie,1985:1).

On 30 Dec 85, HQ AFLC/MMM sent a letter to each ALC tasking them to comment on the concept "minor fit" change. The draft policy on "minor fit" changes using preferred spares was:

> the ALCs may approve minor fit changes as preferred spare actions if the fit changes do not exceed 8 clock hours or 25 man-hours, and there are no changes to support equipment, tooling, change to simulators/trainers, etc. AFLC will approve (case-by-case) those changes that exceed 8 clock hours / 25 man-hours and involve changing to SE, tooling, etc. (Murdock,1986:1)

Oklahoma City ALC responded to the AFLC request with comments in a letter dated 10 Jan 86. They defined a minor fit change as,

> a change requiring a minimum amount of rework of associated parts and materials and is within the skill level of the installing activity. Material requirements must be minimal and consist of common items which are either in stock or are available within the command redistribution. (Wheeler,1986:1)

Ogden ALC also responded to AFLC in a letter dated 10 Jan 86. They defined a minor fit change as

> any change that doesn't change the function of the item's next higher assembly, doesn't require additional special tooling/fixtures, can be accomplished within 8 additional clock hours, and doesn't require changes to other associated configuration items (i.e. system or components which interface with items requiring the 'minor change'), or changes to support equipment. (Milne,1986:1)

Warner Robins ALC responded in a letter dated 14 Jan 86. They said the minor fit change will have to be dealt with on a case by case basis with these two questions in mind (Leachman, 1986:1):

1. How will this change affect the routine maintenance of this aircraft?

2. How will this change affect the operation of this aircraft?

San Antonio ALC said in a letter dated 16 Jan 86, a minor fit change for a preferred spare occurs when (Dunlap,1986:1):

1. All material needs can be satisfied by "normal" bench stock items. These items would not be used in a kit. There would be no reimbursement use.

2. Rework of existing group A items, not to exceed 24 man-hours on field level preferred spare actions.

3. Only Expendability-Recoverability-Repairability-Category (ERRC) code P and N items can be used. No recoverable items are required.

And finally, Sacramento ALC responded in a letter dated 21 Jan 86 and stated, "after careful study, it was determined that such a definition is not viable" (Seaman,1986:1).

On 3 Jun 86, HQ AFLC/MMM sent to each ALC a letter summarizing AFLC's policy on preferred spares request for minor fit changes. According to the letter,

> when a minor fit change is involved in an action which would otherwise meet the criteria for a preferred spares, requests for waiver will be sent in writing to HQ AFLC/MMMP/MMMI for coordinated approval. Include a complete technical description of the preferred spare action and the minor fit change involved. Also include the funding profile with line item breakout (by FY) of all costs i.e., engineering, tech data, kits, trial installation, install labor, etc. The costs involved with minor fit change should be broken out separately. (Crane,1986:1)

IV. Regulations

This section discusses the changes to AFR 57-4 and the AFLC draft supplement to AFR 57-4.

Change to AFR 57-4

On 21 May 86, HQ USAF/LEYY sent a draft preferred spares policy (change to AFR 57-4) to HQ AFLC/MMF for their comments. According to the draft change to AFR 57-4, a preferred spare is

> an individual part of subassembly supplied for the maintenance or repair of systems or equipment which provides desirable or beneficial qualities (e.g. improved reliability and maintainability) when compared to an existing or alternative item (i.e. spare). The item does not affect fit or function of the configuration item. Note: minor fit changes (e.g., changes which are easily accomplished; cable extensions or mounting alterations; changes requiring less than 8 clock hours or 25 man-hours to accomplish and requiring no associated changes to other support elements such as support equipment, simulators, etc.) will be considered a preferred spare on a case-by-case basis as approved by MAJCOM. Change to form only may be done as a preferred spare. (Dunn, 1986:3)

The letter that was attached to the draft change to AFR 57-4 stated, a conflict remains between the modification's form, fit and function control of a configuration item and the preferred spare's form change (Dunn,1986:1). HQ USAF/LEYY suggested changing the definition of the term "modification" in AFR 57-4 as one way to resolve this conflict. They proposed the following definition: modification is "an alteration to a produced material item (e.g., a stock number item). The alteration changes, as a minimum, the fit and function of the item" (Dunn, 1986:1). However, the phrase "fit and function" should be "fit or function" to allow a change to either the fit or function of an item to still be a modification (Spillers,1986:1).

In response to HQ USAF/LEYY's request, HQ AFLC/MMP sent a letter, dated 8 Jul 86, recommending a separate document for guidance on replacement spares, and a separate review process. Since AFR 57-4 is devoted to modification approval and management, it should not include guidance on replacement spares. Instead AFR 57-4 should refer readers to an AFLC supplement regulation that would define implementation procedures (Spillers,1986:1). In addition to a separate document being published, the AFLC also needs to establish a separate requirements review process. The Configuration Control Board (CCB) would no longer be the appropriate approval forum because a preferred spare would not change the item configuration (Spillers,1986:1).

In December 1986, HQ USAF/LEY sent the proposed revision of AFR 57-4 to HQ AFLC and each of the ALCs for their consideration. Included with the revision was a message, 121930Z Dec 86, in which Air Staff stated their general objective and downplayed the use of modifications. According to the message, Air Staff's general objective is "to provide our managers the flexibility to choose the optimum efficiency solution method (i.e. mod, spare, maintenance) that most quickly and efficiently resolve the problem" (Dunn,1986:2).

Furtermore, Air Staff also downplayed the use of modifications. They expected AFLC to realign current programs and to preclude future submissions of inappropriate class IV modifications (Dunn,1986:3). They also expected AFLC to process those tasks that are common to normal maintenance practice as maintenance tasks and not as modifications (Dunn,1986:3). This message would be regarded with the authority of a regulation until the appropriate regulations were changed.

AFLC Supplement to AFR 57-4

On 28 Oct 88, HQ AFLC/MMM sent to each ALC and several AFLC offices a letter requesting them to comment on the draft AFLC supplement to AFR 57-4. The AFLC supplement is concerned with the Improved Item Replacement Program (IIRP), (formerly the 100 Percent Replacement/Preferred Spares Program). The purpose of the IIRP is "to introduce more reliable and maintainable components, SRUs, and LRUs at an economical rate to the supply system and not the development or the design of new items of supply" (IIRP,1988:2).

The HQ AFLC/MMA responded to the AFLC request on 22 Nov 88. Their major concern was that the IIRP was not consistent with the current policy regarding AFLC implementation of the Acquisition Executive System (AES). According to Col McWilliams, Deputy Chief of Staff for Material Management at HQ AFLC, the AES type management oversight is applied to those programs which "present a higher degree of risk because of the high cost investment, critical AF mission impact or technological complexity" (McWilliams,1988:1). Since the AFLC AES management program only covers preferred spares involving forced attrition, a "separate oversight management of other IIRP procurements should be defined within the AFLC Supplement to AFR 57-4" (McWilliams, 1988:1). In addition, the letter also stated the need "to identify a logical decision point within the preferred spares process to identify potential acquisitions as AES programs" (McWilliams,1988:2).

HQ AFLC/CA, 28 Nov 88, believed the item manager should review not only the impact and applicability to Foreign Military Sales (FMS), but also "review the impact and applicability to other services" (Pansza,1988:1).

Furthermore, the IIRP should provide guidance on how the System Program Manager's (SPM) ranking will be incorporated into the final decision when multi-aircraft are involved (Pansza,1988:1).

HQ AFLC/MMT, 29 Nov 88, noticed that the IIRP could become part of their Quality Spares (QS) strategy. For instance, SPM and commodity item managers or equipment specialists could use LCC/R&M models to select R&M candidates for product improvement (Rothery,1988:3). The IIRP could fulfill this requirement by stating (Rothery,1988:3):

1. an R&M improvement is not considered to be a performance improvement.

2. an R&M improvement does not necessarily affect form, fit, and function.

On 6 Dec 88, Warner Robins ALC/MMM stated in their letter to HQ AFLC/MMM that they failed to see how any component could be rapidly introduced into the supply system (Newsom,1988:1). They also asked several significant questions. For instance, "how are Air Force personnel to know this improved part is available in the market place" (Newsom,1988:2)? Besides trade journals, contractor offers, and unsolicited proposals, the Air Force needs to research opportunities for preferred spares.

According to Col Newsom, Chief Resource Manager for the Material Management Directorate at Warner Robins ALC, to encourage research, the Air Force needs to become more flexible with replenishment spares (BP15) funds by using BP15 funds for engineering tasks and other development costs (Newsom,1988:2). Warner Robins ALC/MMM also questioned why a complete or partial LCC study should be completed for an item that has not been procured in 15 years and is no longer available or supportable" (Newsom,1988:2)?

On 9 Dec 88, Oklahoma City ALC provided HQ AFLC/MMM with their comments on the AFLC supplement to AFR 57-4. They concluded, "this draft has restricted the application of preferred spares to the point it is virtually impossible to get an item approved. If the preferred spares program is to be used to insert technology, more flexibility must be used in the approval process" (Hruskocy,1988:1). They also noted, "the life cycle cost model has not been furnished" (Hruskocy,1988:1).

On 29 Jan 89, Sacramento ALC submitted their comments on the AFLC supplement to AFR 57-4. Their first comment was "this supplement adds a new process that will actually delay the rapid introduction of improved items compared to the current process" (Stauder,1989:2). The letter also noted an LCC study was required without regard to the cost of the replacement program. "On smaller programs, the LCC could cost more than the replacement of an SRU" (Stauder,1989:2).

On 7 Aug 89, HQ AFLC/MMARR provided HQ AFLC/MMIIO with their comments on the IIRP. According to Mr Zimmerman, Chief of the Requirements and Integration Branch at HQ AFLC, proposed supplement to AFR 57-4 was not a logical supplement because, "it would be confusing for someone who manages an IIRP, funded with spares dollars, to look in a regulation governing modifications" (Zimmerman,1989:1).

V. Conclusion

This appendix reviewed a short history of the preferred spare. The Air Force recognized the need for a preferred spare policy because of the problems with the CCB process, the confusion about replenishment spares funding, a desire from Air Staff to speed up the overall product improvement process, and a need for additional Air Force guidance in the regulations. An important part of this policy was defining the preferred spare. The preferred spare had to be different from other modifications. As a result, the Air Force made changes to AFR 57-4 and created an AFLC draft Supplement to AFR 57-4.

APPENDIX B:

The Storyboards

```
 DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

      MINOR REWORK

 1.   Is it necessary?

 2.   How long will it take?

 SELECT ACTION NUMBER:

             HOOK BOOK   F5
             HELP        F6
```

Figure 13. Minor Rework.

```
              DECISION SUPPORT SYSTEM

             PREFERRED SPARE LCC MODEL

   MINOR REWORK: Is It Necessary? Select
   action number one to see a picture of
   the old LRU or action number two to see
   a picture of the new LRU. Is the new
   LRU different than the old LRU?

   1.   OLD LRU PICTURE

   2.   NEW LRU PICTURE

   SELECT ACTION NUMBER:

                             HOOK BOOK   F5
                             HELP        F6
```

Figure 14. Minor Rework - Is It Necessary?

DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

MINOR REWORK - How Long will it take? Select action number one for a modification or action number two for a preferred spare.

1. Modification: more than 8 clock hours or 25 man-hours.

2. Preferred Spare: less than 8 clock hours or 25 man-hours.

SELECT ACTION NUMBER:

HOOK BOOK F5
HELP F6

Figure 15. Minor Rework - How Long Will It Take?

DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

ATTRITION. Select action number one for instructions on normal I&S groupings or action number two to determine screening intervals.

1. NORMAL ATTRITION

2. FORCED ATTRITION

SELECT ACTION NUMBER:

HOOK BOOK F5
HELP F6

Figure 14. Attrition.

DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

INVOKE THE LCC MODEL: Acquisition Strategy. Select action number one to input the number of years for this study. Select action number two determine the number of new LRUs to install for each fiscal year.

1. Number of Years.

2. Acquisition Strategy.

SELECT ACTION NUMBER:

HOOK BOOK F5
HELP F6

Figure 17. Acquisition Strategy for LCC Model.

DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

COST-BENEFIT ANALYSIS. Select action number one to quantify the benetfits or action number two to determine the benefit/cost ratio.

1. Quantify Benefits.

2. Benefit/Cost Ratio.

SELECT ACTION NUMBER:

HOOK BOOK F5
HELP F6

Figure 18. Cost-Benefit Analysis

```
                DECISION SUPPORT SYSTEM

              PREFERRED SPARE LCC MODEL

                 REQUEST FOR APPROVAL

        1.   Preferred Spare

        2.   Description

        3.   Results of Cost Analysis

        4.   Approval Authorities

        SELECT ACTION NUMBER:

                                  HOOK BOOK   F5
                                  HELP        F6
```

Figure 19. Request for Approval.

```
              DECISION SUPPORT SYSTEM

             PREFERRED SPARE LCC MODEL

  REQUEST FOR APPROVAL:  Preferred Spare.
  Please provide the required information.

     1.   Date:
     2.   ALC:
     3.   National Stock Number:
     4.   Part Number:
     5.   Project Name:
     6.   Application
          A.  Next Higher System:
          B.  Weapon System:
     7.   Unit Cost:

                                 HOOK BOOK    F5
                                 HELP         F6
```

Figure 18. Request for Approval - Information.

DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

REQUEST FOR APPROVAL: Description.
Please answer the following questions.

1. Explain what is to be done and why.

2. If there is more than one spare involved, will there be a Kit?

3. Is this 100% replacement?

4. Has this program been presented as a modification and rejected? If yes, why?

5. Can the program be completed? If not, why not?

HOOK BOOK F5
HELP F6

Figure 21. Request for Approval - Questions.

DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

Request for Proposal: Results of Cost Analysis.

1. Acquisition Strategy

2. Breakeven Point

SELECT ACTION NUMBER:

HOOK BOOK F5
HELP F6

Figure 22. Request for Approval - Results.

DECISION SUPPORT SYSTEM

PREFERRED SPARE LCC MODEL

REQUEST FOR APPROVAL: Approval Authorities. Select the Acquisition Level to find out Program Manager, Program Executive Officer, and Acquisition Executive.

1. $1 Million/year or $15 Million total

2. $5 Million/year or $50 Million total

3. $25 Million/year or $100 Million total

4. More than $25 Mil/yr or $100 Mil total

SELECT ACTION NUMBER:

HOOK NBOOK F5
HELP F6

Figure 23. Request for Approval - Approval Authorities.

APPENDIX C:

Preferred Spares LCC Spreadsheet Model

INPUTS	OLD LRU	NEW LRU	SUMMARY
UNIT COST			
MTBF			OLD LRU:
MTTR			
CONDEMNATION RATE			NEW LRU:
REPAIR LABOR RATE			
AVERAGE OPER HRS			
NUMBER OF SYSTEMS			
TOTAL OPER HRS/YR			
DISCOUNT RATE			
SELECT: 3 FOR 10%			
SELECT: 2 FOR 7%			
SELECT: 1 FOR 5%			
STARTING YEAR			

ACQUISITION STRATEGY	FY90	FY91	FY92	FY93	FY94
NEW LRU INSTALLED					
OLD LRU INSTALLED					
CUM OPER HRS * SYS					

ACQUISITION COST	FY90	FY91	FY92	FY93	FY94
1. PROD TOOLS/TEST EQ					
2. PROD START-UP					
3. SYSTEM ACQUISITION					
4. SHIP/STORE CONTAIN					
NUM CONTAINERS					
COST/CONTAINER					
5. PRE-PROD ENGINEER					
6. PRE-PROD UNIT REFUR					
NUMBER OF UNITS					
AVG UNIT COST					

7. INSTALLATION
   NUMBER OF SYS
   COST/SYS

8. REUSABLE CONTAINERS

9. TECHNICAL DATA
   TOTAL COPIES
   TOTAL PAGES
   DEV COST/PG
   PRINT COST/PG

10. INITIAL TRAINING
    NUM COURSE HRS
    DEVELOPMENT COSTS
    COST/HR
    INSTRUCTOR COST
    NUM INSTRUCTORS
    AVG HRLY RATE
    TRAINEE COST
    COURSE HRS + 8
    NUM TRAINEES
    HRLY RATE
    NUM OF DAYS
    PER DIEM
    TRANSPORTATION

11. TRAINING DEVICES
    NUM DEVICES
    AVG UNIT COST

12. NEW/MOD FACILITIES
    NUM SQ FEET
    COST/FOOT

13. INITIAL ITEM MGT
    COST/ITEM

14. MISCELLANEOUS

15. WARRANTY

16. HARDWARE SPARES
    UNIT COST
    NEW LRU DEMANDS
    OLD LRU DEMANDS

17. SUPPORT EQUIPMENT
    COST/SE
    SE HRS/DEMAND
    SE AVAIL HRS
    SE UTIL HRS
    SE UTIL/SE AVAIL
    NUM OF SE

ACQUISITION COST
DISCOUNT FACTOR
DISCOUNTED ACQ COST

YEAR	FY90		FY91		FY92		FY93	
OPER AND SUP COST	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1. LABOR								
OPERATION LABOR								
OPERATOR/SYS								
LABOR RATE								
REPAIR LABOR								
OLD LRU REPAIR								
2. SE REPLACEMENT								
NUM SE								
COST/SE								
3. RECURR TRNG								
TOT MAINT MEN								
TURNOVER RATE								
TRNG COST/MAN								
4. REPAIR PART/MAT								
AVG COST/REPAIR								
CONSUMABLES								
5. CONDEMNATION SPARE								
NUMBER CONDEMNED								
6. TECH DATA REVISION								
TOT PGS REVISED								
DEVELOP COST/PG								
NUM TECH DATA								

7. TRANSPORTATION
   REPAIR TRIPS * 2
   REPAIR TRIP COST
     WEIGHT
     PACKING/HAND
   NRTS TRIPS
   NRTS TRIPS COST
     WEIGHT
     PACKING/HAND

8. RECURRING FACIL
     NUM SQ FEET
     COST/FOOT

9. RECUR ITEM MGT
   NEW INVENTORY
     NEW LRUs
   NEW STOCKED
     SPARES
     COST/SPARE

10. CONTRACTOR SERVICE

11. ENGINEERING CHANGE

12. MISCELLANEOUS

O&S COST
DISCOUNT FACTOR
DIS O&S COST

CUM DIS O&S (OLD)
CUM DIS ACQ/O&S (NEW)
NET SAVINGS (LOSS)

TABLE OF DISCOUNT FACTORS

APPENDIX D:

The LCC Model Validation

The Data

The F-15 RLG (Preferred Spare):

Acquisition Strategy	FY88	FY89	FY90
Litton:	0	355	53
Honeywell:	53	299	56

Acquisiton Cost	FY88	FY89	FY90
1. Installed Unit Cost			
Litton:	0	$32,442,867	$4,843,583
Honeywell:	$5,093,729	$28,736,318	$5,382,053
2. Spares Cost			
Litton:	0	$2,614,166	$390,284
Honeywell:	$330,211	$1,862,887	$348,902
3. WRSK Cost			
Litton:	0	$78,309	$11,691
Honeywell:	$483,989	$2,730,427	$511,384
4. RIW Cost			
Litton:	0	$4,007,746	$598,339
Honeywell:	$642,235	$3,623,176	$678,588
5. Battery Modification:	$2,950,000		
6. Technical Orders:	$700,000		
7. Batteries:	$68,598	$846,478	$141,080
8. Battery Test Sets:	$25,746	$317,700	$52,950

The F-15 RLG (cont)

O&S Cost	FY88	FY89	FY90	FY91	FY92	FY93	FY94
Labor (rest)	496	6831	6381	5688	5542	5542	5542
Battery (rest)	10931	145819	168300	168300	168300	168300	168300
Depot (note: $1,772,221 rest)	0	0	0	0	0	210528	1694712

The F-15 LN-31:

O&S Cost	
1. Deferred Spares: $29,707,753 in FY91	
2. Repair Labor	
A. Flight Line:	$123,400 each FY (3772 R&R)*(1.5 MTTR)*($21.81/hr)
B. Base Maint:	$658,133 each FY (3772 Repairs)*(8 MTTR)*($21.81/hr)
3. Depot Maint:	$13,597,743 each FY
4. Battery Maint:	$371,076 each FY

The Results

	AF Study	LCC Model
Constant Cost	1993	1993
PV (10% DR)	1995	1995
PV (5% DR)	N/A	1994

Table 8. The LCC Breakeven Points (in FY).

This appendix contains six graphs made using the F-15 LN-31/RLG data. The first two graphs, Figures 24 and 25, show the results of the actual Air Force study. Figure 24 plots the O&S cost for LN-31 and the LCC (ACQ and O&S) for the RLG in cumulative constant dollars and shows the break-even point in 1993. A third line shows the net loss when its below the zero line or the net savings when its above the zero line. Figure 25 is similar to Figure 24. The difference is the cost in Figure 25 takes into account the time value of money by using a discount rate of 10%. As a result, the breakeven point moved from 1993 in Figure 24 to 1995 in Figure 25.

The next three graphs, Figures 26 through 28, show the results of the Preferred Spares LCC model. Figure 26 is compared to Figure 24 and Figure 27 is compared to Figure 25. Figure 28 is the same as Figure 27 except a 5% discount rate is used instead of the 10% rate. The Air Force recommends using a 10% discount rate. However, the analyst should report any important observations made using the 5% discount rate. In this instance, the breakeven point moved back from 1995 (10% discount rate) to 1994 (5% discount rate).

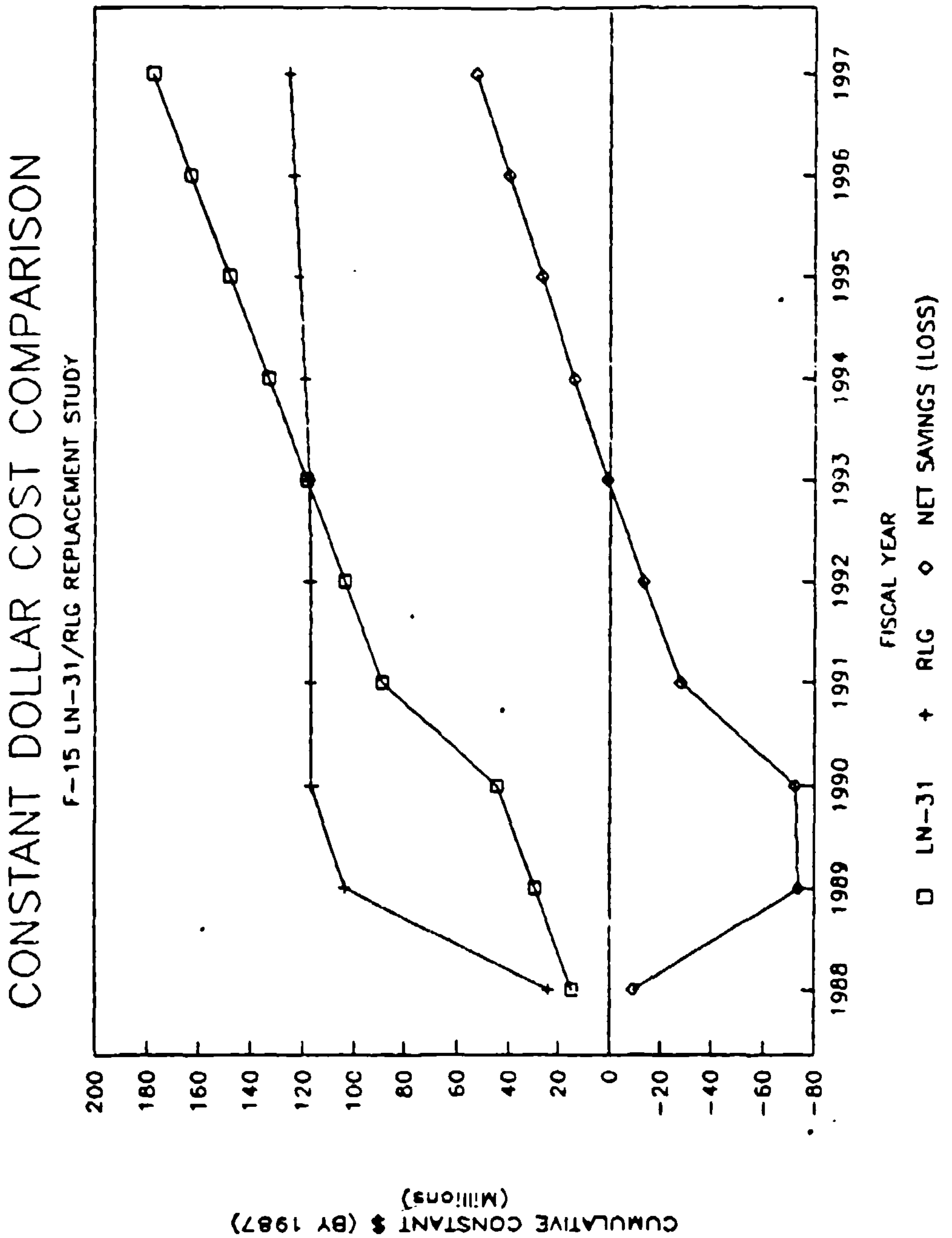


Figure 24. Constant Dollar Cost Comparison (F-15 LN-31/ RLG Replacement Study).

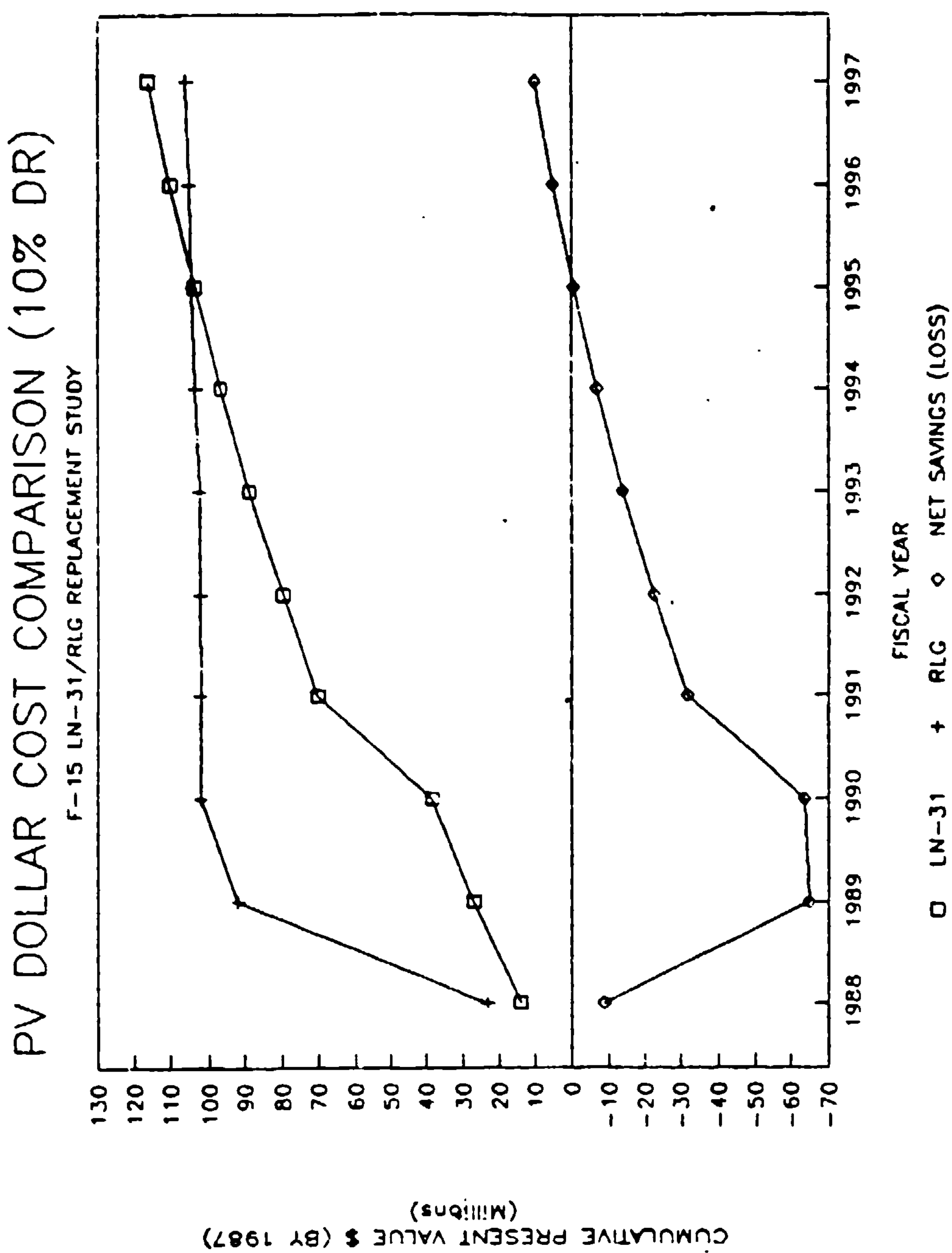


Figure 25. PV Dollar Cost Comparison - 10% DR (F-15 LN-31/RLG Replacement Study).

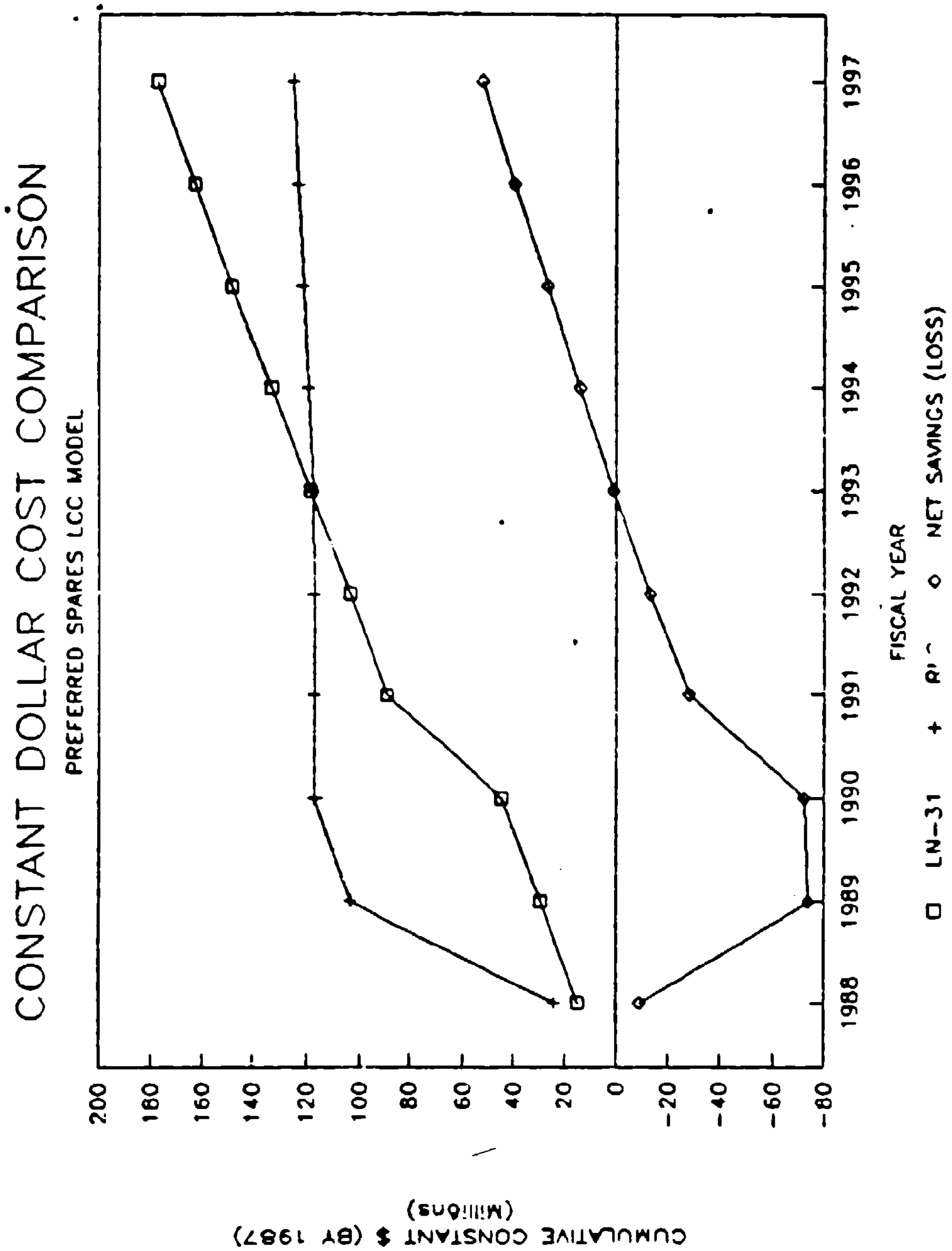


Figure 26. Constant Dollar Cost Comparison (Preferred Spare LCC Model).

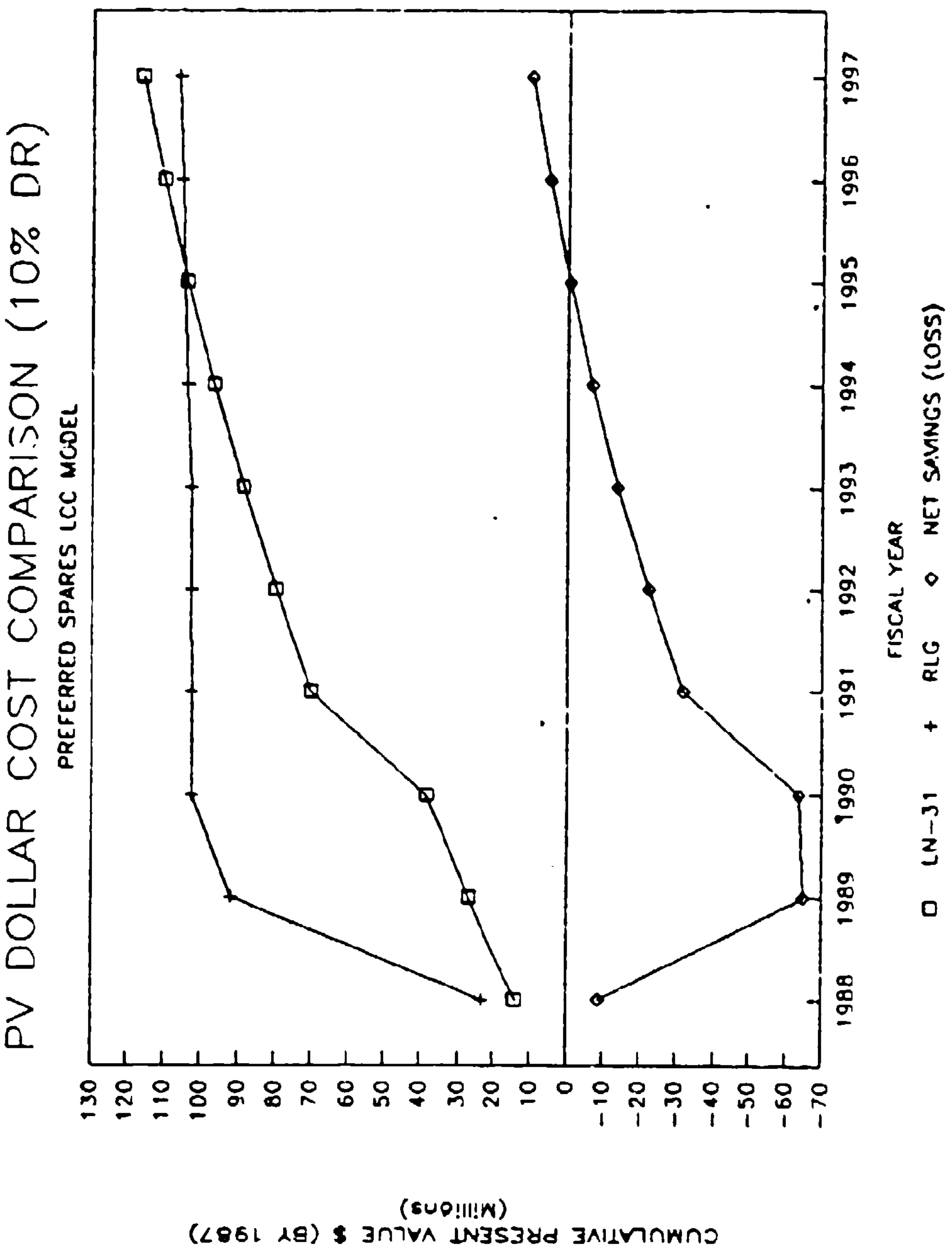


Figure 27. PV Dollar Cost Comparison - 10% DR (Preferred Spare LCC Model).

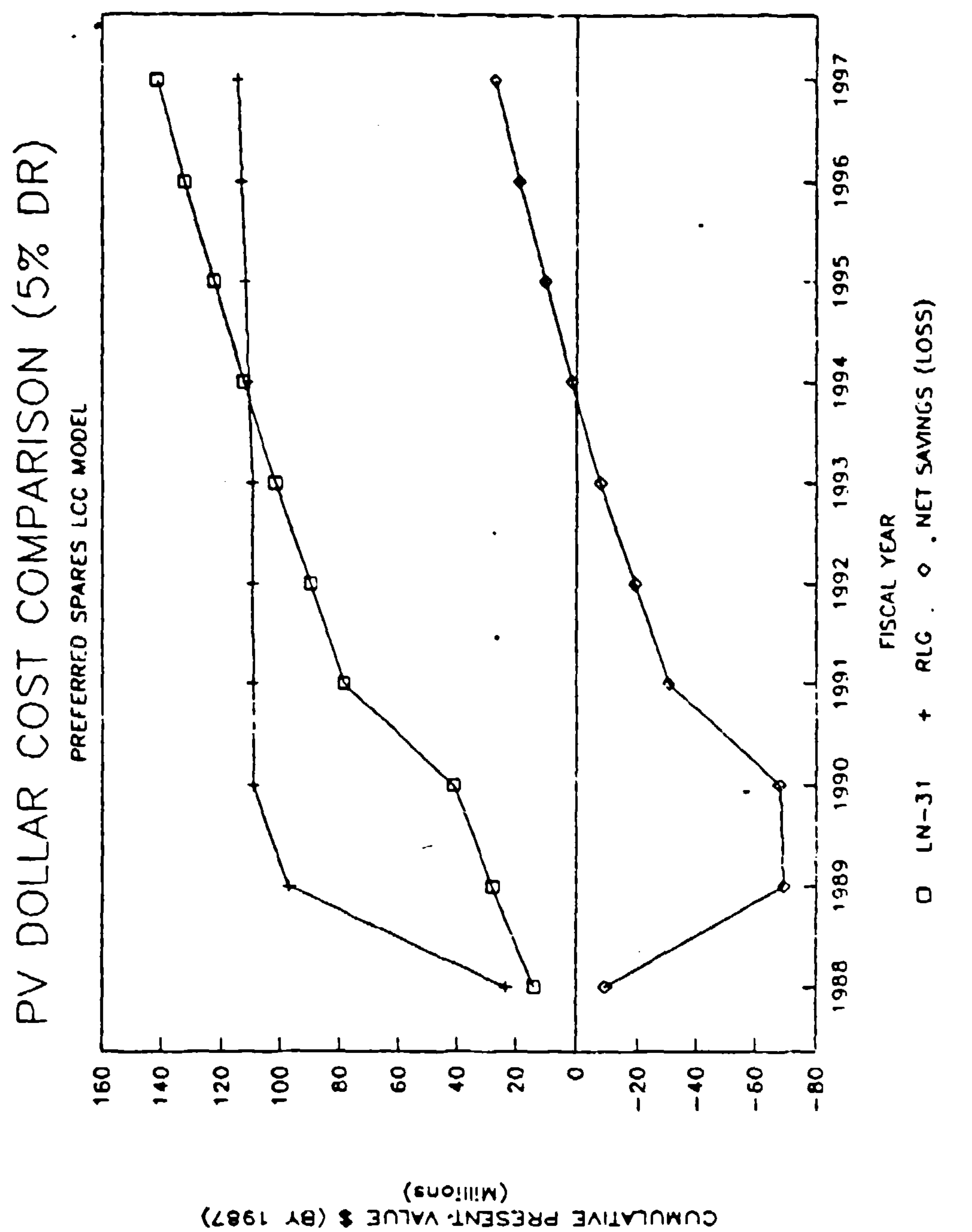


Figure 28. PV Dollar Cost Comparison - 5% DR (Preferred Spare LCC Model).

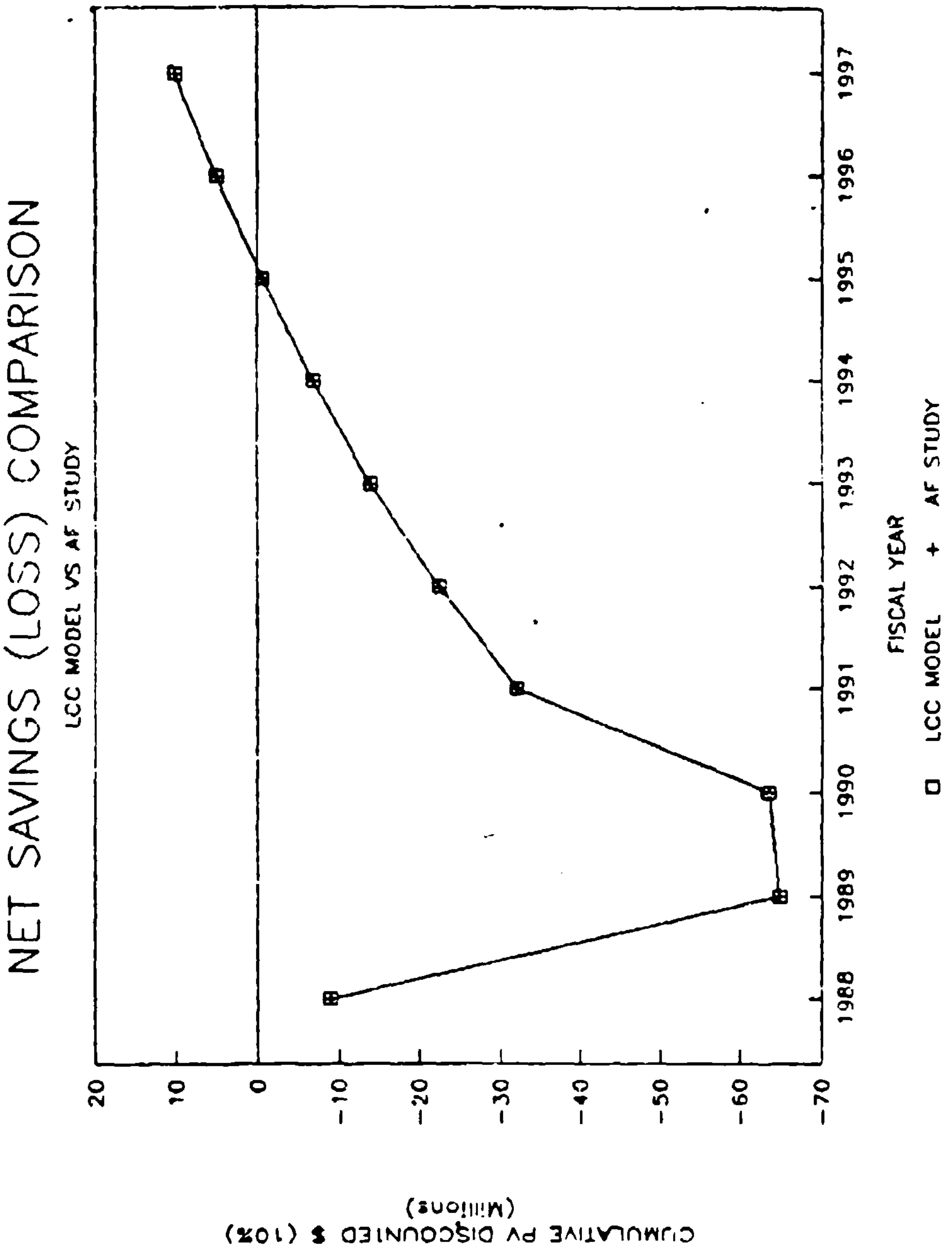


Figure 29. Net Savings (Loss) Comparison (LCC Model vs AF study).

Appendix E:

The Concept Map

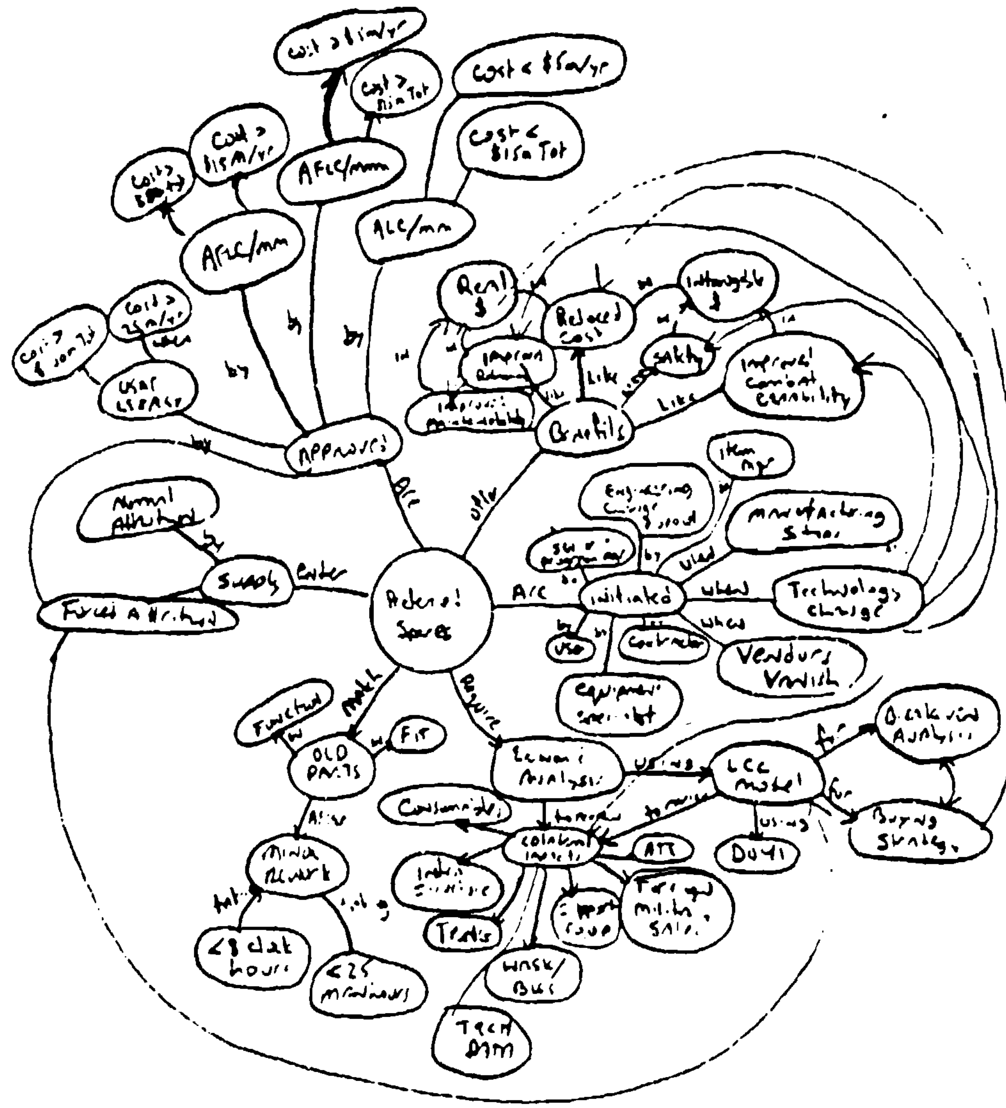


Figure 30. The Concept Map for the Prefferd Spare Problem.

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